AN INVESTIGATION OF THE RELATIONSHIP BETWEEN MIDDLE SCHOOL SCIENCE TEACHERS' KNOWLEDGE AND BELIEFS REGARDING THE COHERENCE AND CONNECTIONS AMONG SCIENCE CONCEPTS AND THEIR CLASSROOM PRACTICES

A DISSERTATION

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ABSTRACT

In the last three decades, the United States has experienced many science education reform initiatives resulting in mixed success. Recently, research has found teachers' beliefs about their content and teaching have influence on what is taught. This investigation attempts to learn about the relationship between middle school teachers' beliefs and knowledge regarding the coherence and connectedness of science concepts and their classroom practice. This phenomenological investigation used an inductive qualitative research approach with multiple instruments and processes including; a survey, interviews, classroom observations, concept maps and classroom materials for data. The results suggest that middle school science teachers' ability to teach science in a connected and coherent fashion may be tied to their mental schema for organizing science ideas, curriculum materials, and their reflections on what they are teaching and why. Further research should help isolate and mitigate outside influences leading to a better understanding of teachers' beliefs about science.

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Chapter I: The Problem

Introduction

In the last three decades, the United States has experienced several large scale and many smaller science education reform initiatives. Some of the efforts have been curriculum based; others have focused on improving the practice of teachers; and some have worked to affect all aspects of the education system. Each has had an impact. Yet sustained or broad-based reform has not been achieved (Bybee, 1997). Recently, research has identified that teachers' beliefs about their content and teaching have a strong influence on what is taught. This may suggest that reform initiatives must go beyond the implementation of specific instructional practices, materials and processes of science education to examine teachers' thinking and how it impacts their curriculum and instruction.

At the core of each reform effort was the question of who defines the content to be learned, and who ensures the opportunity to teach and to learn it well (DeHart Hurd, 2001; National Science Board, 1999). A recent answer has been the recommendations encompassed within national and state standards. Attention to what teachers know and believe about science content is sometimes lost in the fervor to define and assess the knowledge and skills of students (Tobin & LaMaster, 1995). This lack of understanding about teachers' knowledge and beliefs has prompted a renewed emphasis of research on teachers' preparation and thinking about science. This research investigates teachers' factual knowledge and the way they organize and structure this knowledge for teaching.

Lee Shulman initiated much of this research in an effort to explore and to understand the connection between what teachers know and how they teach. He created the term "pedagogical content knowledge" (Shulman, 1986a, 1986b) to mean the ability of teachers to transform their content knowledge into instructional situations allowing students to understand the ideas. This area of research seeks to identify and to describe the nature of the distinctive body of knowledge held by a teacher that weaves the knowledge of the subject matter with knowledge of pedagogy. Research indicates that "experts" in a field have a well-developed subject matter schema or structure on which to

build new knowledge (Bransford, Brown & Cockling, 2000). This mental comprehension and transformation of science as a discipline by teachers in this investigation will be called, 'subject matter structure'. Subject matter structure has been used in previous research as a way to describe the conceptual framework or schema which teachers have about their specific discipline and general content knowledge of science and how they decide to teach it (Gess-Newsome & Lederman, 1995; Lederman et al; 1994. Hashweh, 1986). Subject matter structure (SMS) as it will be used in this study will describe an individual teacher's personal understandings of the publicly defined disciplinary structure of science.

Research on teacher knowledge and beliefs has indicated that there is a central role for teachers' knowledge and beliefs in how they teach (Abd-El-Khalick, F., Bell. R. & Lederman, 1998; Brickhouse, 1990; Cronin-Jones, 1991; Kennedy, 1990; Luft, 1999). The research on teachers' content knowledge is not new, as there were several attempts to systematically explore the relationship between teacher knowledge and student achievement in the 1970's (Gess-Newsome, 1999). The exploration of teachers' knowledge and beliefs is a growing area of study and is represented in a recent book titled *Examining Pedagogical Content Knowledge: The Construct and its Implication for Science Education* (Gess-Newsome & Lederman, Editors, 1999). The sophistication, complexity, methodology and focus of research on teacher knowledge and beliefs have helped develop better conceptions of teachers' subject matter structure.

Current research about teachers' subject matter knowledge has provided many new insights, but unfortunately has been flawed. For instance, the major focus of much of the current research on teachers' subject matter structure has concerned teachers' beliefs about the nature of science. Little research has examined the coherency and connectedness of science taught as related to the teachers' beliefs about science. The way teachers structure their knowledge is key to understanding why they teach the science they do.

An additional flaw is the assumption by researchers about the methodology for collecting teacher knowledge about science. Interviewing teachers about their content knowledge provides a reflection of their theoretical or conceptual knowledge, but their knowledge does not necessarily translate into their practice. Another method for the

collection of knowledge is the use of a concept map, which requires teachers to display their thinking. This method is limited in that it does not necessarily represent what they actually teach, but what they may believe. The exploration of teachers' content knowledge, its structure and how it is displayed in the classroom is needed to determine the nature of their subject matter structure and how it is transferred to a classroom. It can also help determine if the subject matter structure identified has not been a consequence of the research method.

Statement of Problem

If teachers have a subject matter structure which influences their classroom practice, being able to identify all aspects of their subject matter structure (SMS) may have significant implications for teacher preparation, evaluation and inservice programs. Research has begun to articulate aspects of teachers' SMS and their practice. However, there is little examination of whether the teachers' SMS about science content is coherent and connected to other ideas in science, and to what extent these aspects of their SMS get translated into classroom practice.

Research has attempted to understand the relationship of teachers' subject matter knowledge and beliefs with teaching practices. There are several aspects of teachers' beliefs and knowledge that have been identified as a part of the SMS. Those that relate to the preparation of teachers and beginning teachers are exemplified by findings of teachers with weaker content preparations: i.e. there is a lower quality of classroom discourse between the teacher and student (Brickhouse, 1989), teachers communicate alternative conceptions in science to their students (Atwood & Atwood, 1996; Klaassen & Lujnse, 1996; Lee, 1995), teachers delivered less effective instruction of middle school students (Lee, 1995; Cronin-Jones, 1991), and teachers lacked confidence in their subject area knowledge leading to fragmented and disjointed content (Abd-El-Khalick, Bell & Lederman, 1998; Lederman, Gess-Newsome & Lantz, 1994).

Research findings for practicing science teachers indicate that their current content knowledge may not be adequate for teaching science today. For example, teachers' knowledge of science may not be sufficiently integrated across the science

disciplines or may be one dimensional (Arzi, White & Fensham, 1987; Abd-El-Khalick & Boudaoude, 1997). Experienced teachers bring more declarative knowledge which is more traditionally presented (Gess-Newsome, 1999) and their knowledge is most commonly based on their college and high school course work and the textbooks they currently use in their classrooms (Adams & Krockover, 1997). When experienced teachers are asked to teach out of their area, they revert to many of the behaviors and strategies used by inexperienced teachers (Gess-Newsome, 1999). Other characteristics of experienced science teachers are that they consider a variety of learning experiences both in and out of the classroom, and they bring to bear a structured, relatively coherent body of knowledge (Hewson, Kerby & Cook, 1995; Carlson, 1987) to those experiences. Teachers with constructivist views are more likely to use a richer set of strategies for instruction, conceptual change models of learning, and to detect students' alternative conceptions of content than do their empiricist colleagues (Hashweh, 1996, 1989).

Research findings indicate that all teachers, new or experienced, significantly alter intended curricula to make them more congruent with their own teaching orientation and belief systems (Schmidt, et al., 1996; Cronin-Jones, 1991). Also, teacher beliefs about the ability levels of students and the importance of student outcomes exert powerful, and potentially negative, influences on the curriculum implementation process. Years of teaching science with these contextual influences can also shape teachers' views about science. Teachers may also restructure their understandings of the nature of science to fit the type of science they have been teaching in school (Brickhouse, 1989). In summary, the contextual research findings show that it is possible that "the ease with which a subject matter structure affects classroom practice (if at all) is as much a function of the relative complexity of the knowledge structure of the teachers' understanding as it is related to curriculum constraints, administrative policies, management concerns, and so forth" (Lederman, Gess-Newsome, & Latz, 1994. p. 144).

The literature dealing with science teachers' SMS and their practice provides some clarity, but has limitations in methodology and leaves many unanswered questions about a teachers' SMS and whether it identifies teachers' thinking about science being coherent and connected, which leads to a need for further research (Luft, 1999; Pomeroy, 1993; & Roth & McGinn, 1998) about how teachers think about these two factors.

The purpose of this investigation is to answer the research question:

What is the relationship, if any, between middle school teachers' beliefs and knowledge regarding the coherence and connectedness of science concepts and their classroom practice?

In addition, three other questions are included in this investigation to tease out and identify specific aspects and impacts of teachers' thinking about the coherence and connectedness of science.

1. Do science teachers believe that science, as a discipline, is a connected and coherent field of study, or is it comprised of separate areas of study?

2. How does a science teacher's imposition of knowledge and beliefs affect the effectiveness of curriculum materials at the first three levels of the Third International Mathematics and Science Study (TIMSS) tripartite model of curriculum?

3. Does the belief about the coherence and connections of science impede or facilitate effective science instruction?

The research conducted involved teachers, so also included here is an assessment of possible testing effects, which may result from investigations of this sort.

Significance of the Study

This research has the potential to provide processes for the identification of additional and important factors that influence the quality of science teaching, and aid in the delineation of factors that facilitate or impede the teaching of science. Both theoretical and practical implications exist for the findings of this investigation. In terms of the theoretical aspects, a further identification and definition of knowledge structures contribute to this area of research in science education. Past research has illustrated the existence of teacher SMS. Other research has shown that science teachers conduct their classes in a variety of ways depending on many factors, including their SMS. Much of

this research has used methodologies of assessing the SMS and its influence, which may have introduced bias or may have been limited in illustrating what content is actually taught. The focus of this research study is to clarify the nature and influence of the SMS of middle school science teachers, specifically SMS related to the coherence and connectedness of science, while using research methodologies that reduce the bias and provide a more comprehensive picture of how the teacher's SMS relates to her practice.

From a practical perspective, a better understanding of a teacher's SMS about science and its impact on teaching is critical for teacher preparation, evaluation and inservice programs. If it is found that the SMS impacts the teaching of science and that the SMS translates into whether science is coherent and connected, then teacher preparation programs with new or existing teachers should be reviewed. If this research cannot identify any impact, this area would be an unproductive avenue of research.

If this research finds that the way that teachers think about science affects what science they teach, then the formation and enhancement of teachers' SMS may significantly affect their ability to learn and present science in their classroom. In that case, further identification of the SMS should occur. New findings could stimulate the research to identify the best means to facilitate the development of SMS for both preservice and inservice teachers, lowering the differences in the teachers' level of expertise. If this research area is productive, then there are significant implications for subject matter education, professional teacher education, and inservice education of science teachers for improving the implementation of science reform efforts.

Chapter II: Literature Review

Introduction

Since the 1980s when Lee Shulman and his colleagues developed a theoretical framework to better understand the knowledge and beliefs of teachers, research about teachers' thinking has grown significantly. As a result, the research area of teacher beliefs and knowledge is changing. This research area challenges the understanding of the complexity of teachers' thinking about science and science education.

In this study, I will make a distinction between teacher knowledge and beliefs about science and teacher knowledge and beliefs about science education. Science constitutes a field of study, while science education is the educative process that uses science as its content. I make this distinction because teachers have beliefs about both science and science education. Teachers' beliefs about science as a discipline are related to their concepts of the structure, function and development of science (Abd-El-Khalick. & Boujaoude, 1997). These beliefs might, for example, include a particular theory about the structure of the universe such as the expanding universe, or the expanding and contracting universe model. This type of knowledge is important, because it can be time sensitive. One theory may be well accepted today, but unknown twenty years ago. Another example might be a teacher who believes that science is conducted in a purely objective manner and is absolute in the results it produces; another teacher might believe that science is more tentative and can be culturally and socially subjective. These differences in a teacher's beliefs about the content of science could affect how and what science she/he teaches.

Teachers' beliefs about science education are different from those about science because they include ideas such as practical instructional strategies (Roth & McGinn, 1998), materials to use, and content translation of the science for their different students. These types of opinions can cause a teacher to change the curricular content based on beliefs about how students learn (Cronin-Jones, 1991). For example, a teacher might use pedagogy that involves the memorization of the periodic table in chemistry, because she sees that as the only way students will learn that aspect of chemistry. Another teacher

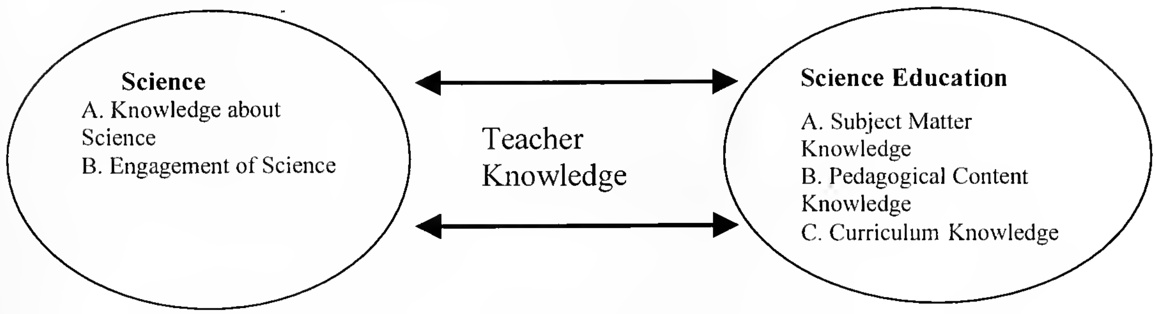
might focus on student exploration with various substances and then categorize those substances according to their characteristics. Both instructional processes have similar ends. Beliefs about science education are focused on the interaction of the teacher, student and the content of the discipline. They have a pedagogical rather than a disciplinary emphasis. There are many areas of overlap between science and science education, but they have been documented as distinct in the literature. I will attempt to explain the complexity of each as it relates to teacher practice.

Components of Teachers' Beliefs

Beliefs and knowledge are two different terms with potentially different meanings, although they are often used together in the research on teachers' beliefs and knowledge. One definition connects the two terms. "A belief is knowledge that is viable in that it enables an individual to meet her goals in specific circumstances. Beliefs are tied to the situations in which actions are contemplated" (Tobin & LaMaster, 1995. p.226). Because the difference between beliefs and knowledge is more of degree than kind (Pajares, 1992.), in this study I will use both words with the intent that they are the same when operationally applied in the classroom. It is the relationship of both factors - belief and knowledge - on actions that is important in this study, not the distinction between the two terms. Precedence has been established for using these two terms as one by Gess-Newsome, (1999) in a broad synthesis of ideas about teachers' beliefs and knowledge. Categories based on the structure of the discipline of science and the implementation of teacher knowledge and beliefs in classroom practice will be used instead of attempting to separate beliefs and knowledge.

Teachers' beliefs about science and science education are related to their knowledge and experience in both science and science education (Adams, 1997; Cronin-Jones, 1991; Brickhouse, 1989) (Figure 1). Teachers develop and form their beliefs from formal and informal educational experiences in their lives; sometimes they develop alternative concepts.

Figure 1: Conceptual Model for Science Teachers' Knowledge and Beliefs



Science Beliefs

A teacher's overall concept of science, as a discipline, is her/his philosophy of science or a broad conceptual understanding and epistemology of science. The teachers' epistemology of science has been examined and explored through various techniques and instruments to determine what teachers say they believe and how it is displayed in the classroom. A conceptual understanding of science is important as it provides the basis for a teacher's perspectives and dispositions toward science. This knowledge has been divided into categories for better explanation.

Two general categories are the knowledge about and engagement in science (Roth & McGinn, 1998). These two categories are similarly described by Brickhouse (1989) using other terms - substantive knowledge and syntactical knowledge. Another framework presented by Kennedy (1990) describes three categories of knowledge in a discipline: content of the subject, organization of the content, and methods of inquiry used in that subject. In this study, I will use the two categories proposed by Roth and McGinn (1998) as they are more comprehensive, including the nature of science as a part of the discipline of science. This Science Knowledge Framework (Table 1) illustrates these two categories.

The first part of the chart categorizes science knowledge into *structure* and *function of science* (Abd-El-Khalick, & Boujaoude, 1997). The categories within the *structure* of science include specific declarative knowledge such as science facts and processes as well as science concepts (i.e. forces make things move or animals are interdependent with other organisms), and interrelated concepts within science such as

broad concepts of energy or matter. The categories within the *function* of science include the connection of science ideas and concepts to social and personal activities. For example, the development of science as a discipline requires an understanding of the historical process within which the knowledge was created. It also requires an understanding that the creation of science knowledge is a dynamic process (Abd-El-Khalick & BouJaoude, 1997).

A teacher who understands science as described in these two categories might demonstrate her/his knowledge of it by being able to read, write, and communicate in science. She/he also knows the scientific enterprise, its role, and what it can and cannot provide (Shamos, 1995). This level of scientific literacy could be called functional scientific literacy or the lexicon of science.

Table 1: Science Knowledge Framework

Knowledge About Science (Substantive)	1. Structure of Science	a. Science Facts and Processes
		b. Science Concepts
		c. Interrelationship of Science Concepts
	2. Function of Science	a. Science Ideas and Society
		b. Development of Science
		c. Creation of Science Knowledge
Engagement of Science (Syntactical)	1. Process of Investigation	a. Scientific Investigation
		b. Doing Science
	2. Nature of Science	a. Tentative Nature
		b. Empirically Based
		c. Subjective
		d. Partly a Product of Human Inference, Imagination and Creativity
		e. Socially and Culturally Embedded

The second part of the Science Knowledge Framework includes knowing science by engagement. The *engagement of science* category includes the process of investigation, the doing of science, and the nature of science including aspects of scientific knowledge, such as: science knowledge is tentative, empirically based, subjective, partly the product of human inference, imagination and creativity, and socially and culturally embedded (Abd-El Khalick, Bell, & Lederman, 1998). This *engagement in*

science knowledge includes the basis for the ways in which scientific claims are made and argued. If teachers incorporate this level of understanding of science into their own knowledge of science, they are able to make connections between the sciences, which might represent a true literacy of science (Shamos, 1995).

It should be acknowledged that a teacher's understanding of science is built over many years, beginning with primary school and including informal learning in science extending through her/his university courses into her/his more recent experiences such as reading the science texts in preparation for a class, participating in scientific study in a research facility or industry, or participating in a tour through a nature preserve. These experiences all contribute to one's knowledge of science. How those ideas are solidified into knowledge and beliefs about science is beyond the scope of this study. Nonetheless, the source and construction of science concepts that make up an individual's knowledge and beliefs about science is a complex and extended process.

Science Education

Science education is the activity of teaching science. This area has some of the same components as beliefs about science, but there are some distinctions because of the inclusion of teaching. Shulman (1986) identified a multi-content framework for a professional knowledge base needed for teaching. The framework includes three areas of content knowledge: subject matter knowledge, pedagogical content knowledge, and curricular knowledge. This framework has been applied to science generally or for discipline specific areas such as biology, as the framework refers to the knowledge base of one's subject area and the alternative and useful ways of representing these topics. If a teacher is an expert in biology, she/he will have developed methods for teaching the topic based on her/his knowledge of Biology and any related sciences. Shulman identified how that discipline knowledge is translated into instructional ideas and plans for students. The conceptual framework of disciplinary thinking has also been described operationally as Subject Matter Structure (SMS). The identification of a teacher's thinking and behavior in the classroom as related to the discipline by the term SMS is best described by the following; "... the teachers classroom decisions are located in and contingent upon, a

specific social, cultural, and educational context." (Barnett, Hodson, 2000.) SMS is the comprehension and transformation of the knowledge of the teacher into what she actually teaches.

The term SMS will refer to the type of mental schema of a teacher represented in the Science Education Framework. The first area in this Science Education Framework (Table 2) concerns subject matter knowledge, which will be understood in this study as the components previously described in the Science Knowledge Framework.

Table 2: Science Education Framework

Subject Matter Knowledge	1. Science Knowledge Framework	(Table 1)
Pedagogical Content Knowledge (PCK)	1. What makes the discipline difficult to learn	a. Instructional methods
		b. Management of the science classroom
		c. Knowledge of teachers' own beliefs
	2. Understanding the role of student's prior knowledge	a. Student learning
		b. Teacher beliefs about students ability to learn
Curriculum Knowledge	1. Knowledge of curriculum	a. What is taught
		b. Alternative materials
		c. Alternative environments
	2. Knowledge of connections to other topics	a. Science topics
		b. Other curricular areas

The second area in the Science Education Framework is the *pedagogical content knowledge* including what makes the discipline difficult to learn, how to present certain types of ideas, and an understanding of the role of students' prior knowledge. The third area is *curricular knowledge* of instructional materials, alternatives, and the connections to other topics that students might be studying in other subjects in school.

The Science Education Framework briefly describes aspects of teachers' thinking and ideas that they include in their teaching. Since the first part has already been discussed, I will focus on the two latter parts.

Shulman (1987a & 1987b) explained *pedagogical content knowledge* as including instructional methods, student learning, the teachers' beliefs about the ability of students to learn, management of a science classroom, and knowledge of the teachers' own beliefs about science. As applied for the discipline of science, the task of any science teacher is

to find ways to represent the subject matter to students in ways that allow students to understand science (Kennedy, 1990). In science, students will not learn as well in a passive posture where the teacher gives information to them, but will learn more in an active way by constructing mental images through the use of materials and discussions. If students are passive, they are prone to learn science as isolated facts or incorrect ideas about how things occur. In science, students are likely to construct erroneous models of physical phenomena (Kennedy, 1990).

Further explanation of *pedagogical content knowledge* is found in many documents and studies. The National Science Education Standards (NRC, 1998) identify standards for pedagogical knowledge for teaching science including inquiry and assessment as ways to teach and measure student knowledge while teaching. Classroom management influences learning of science (Lee, 1995; Shulman, 1989), and also falls under the area of *content pedagogical knowledge.* Classroom discourse between the teacher and students has been identified as an area that can be influenced by teachers' knowledge of science (Brickhouse, 1989).

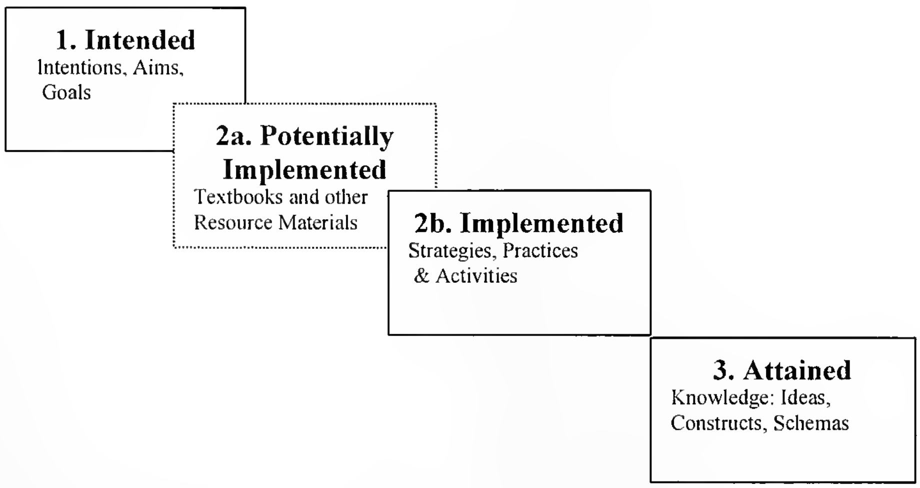
The translation of science into teaching includes the teachers' beliefs about science education because it is the action conducted by teachers. But *pedagogical content knowledge* also includes beliefs about science as a part of teachers' professional knowledge. *Pedagogical content knowledge* includes the teachers' beliefs about the discipline of science as an integral part of their beliefs about science education. People fluent in their subject matter are distinguished from their peers in at least three respects: "1. They know a great deal of specific content. 2. They have formed a variety of complex relationships among the pieces of content. 3. They understand how to approach new problems and dilemmas and how to produce new ideas within a subject" (Kennedy, 1990).

Curricular materials and resources belong in this framework as the *knowledge of curriculum* to teach science and *knowledge of connections to other topics.* Curricular materials and textbooks play an important role in teachers' thinking, sometimes providing a source of teachers' knowledge of science and the sequence of what is taught (Adams & Krockover, 1997). Other examples of teachers' knowledge in this area include the available curriculum materials and the instructional environments conducive to learning

the topic. Research findings also indicate that teachers significantly alter intended curricula to make them more congruent with their own teaching orientation and belief systems (Schmidt, et al., 1996; Cronin-Jones, 1991).

The International Association for the Evaluation of Educational Achievement developed a tripartite model of curriculum to illustrate the potential complexity of the hierarchy and interaction among standards, curriculum goals, textbooks and teachers' beliefs in the implementation of curriculum (Figure 2 adapted from Schmidt, et al., 1996).

Figure 2: Tripartite Model of Curriculum



The *intended* curriculum here refers to an educational system's goals and plans. For the U.S. it represents national, state and district standards and curriculum guides. The *potentially implemented* refers to the curricular materials such as textbooks and other instructional materials. The *implemented* curriculum is the actual representation by the teacher of the two previous levels in the model. And the final level of the *attained* curriculum is what is actually learned by students.

Connections of science ideas to other science disciplines also offer better opportunities for teachers to help students learn science. This is stated similarly in the National Science Education Standards as understanding science requires students to integrate a complex structure of many types of knowledge, including the ideas of science, relationships between ideas, and reason for these relationships (NRC, 1996).

Teachers' knowledge and beliefs about science and science education provide a multidimensional perspective on what makes up teachers' thinking when teaching science. Understanding these two ideas and their interactions provides a way of viewing teachers' choices on a daily basis.

Literature Review About Science Teachers' Knowledge and Beliefs

This section will review research on science teachers' knowledge and beliefs regarding the interaction of science and science education. This review includes five overlapping categories of teacher knowledge and beliefs in science education. These categories, established by Gess-Newsome (1999), were used to summarize literature on what is known about teachers' subject matter knowledge.

The five categories of teacher subject matter knowledge are: *conceptual knowledge, subject matter structure, nature of the discipline*, *content specific orientations to teaching,* and *contextual influences in curricular implementation.* This categorization is substantially different from the earlier frameworks discussed, but is used here as a way to organize the interaction of all the areas in teacher knowledge and beliefs in science and science education. Table 3 outlines these five categories and subsumes the *Science Knowledge Framework* (Table 1) and *Science Education Framework* (Table 2) to illustrate their relationship.

Table 3: Relationship of Conceptual Frameworks

Science Knowledge Framework (Table 1)	**Science Education Framework (Table 2)**	**Gess-Newsome Framework (5 categories)**
About science (Substantive) Engagement of science (Syntactical)	Subject matter knowledge	1. Conceptual knowledge 2. Subject matter structure 3. Nature of the discipline
	Pedagogical content knowledge Curriculum knowledge	4. Content specific Orientation to teaching 5. Contextual influences

The five categories suggested by Gess-Newsome are more specific and helpful in defining the aspects of teachers' knowledge and beliefs. The conceptual knowledge, subject matter structure, and nature of the discipline suggested by Gess-Newsome belong in the substantive knowledge category. For example, the knowledge about science, how the discipline is organized, and how new ideas are discovered is different from what the teacher needs to know about effectively teaching students. The other two areas that Gess-Newsome identified - *content specific orientation* and *contextual influences* in curricular implementation - are examples of syntactical knowledge. These areas are strongly influenced by how a teacher translates the science for her/his students, or the application of the teacher's beliefs into the practice of teaching science, such as a teacher having an environmental bias, and teaching with a stronger emphasis on environmental views rather than some other topical bias. The teaching of science is often driven more by personal beliefs and factors related to working in schools than by the content of science.

These five categories overlap, but in an effort to try to clearly understand the various factors involved in teacher beliefs and knowledge, they will be separated to articulate the various components. Each area will be explained and connections between the areas will be made.

Conceptual Knowledge

The *conceptual knowledge* category is defined by Gess-Newsome as, "the facts, concepts, principles, and procedures that are typically taught" (1999. p. 4) in classrooms. *Conceptual knowledge* includes the interconnected nature of science as well, because science can be impacted by beliefs and social influences, and how individuals personally integrate that knowledge.

Several studies examined the beliefs and knowledge of K-12 teachers in training. The format for these studies varied, but the findings were consistent. Most found that students learning to become teachers did not have confidence in their subject area knowledge; therefore, there was little stability in their subject matter or pedagogy knowledge. Their beliefs and knowledge about science and science education were a result of their college course work, and were fragmented and disjointed with little

evidence of coherent themes (Abd-El-Khalick, Bell & Lederman, 1998; Lederman, Gess-Newsome & Lantz, 1994).

In these studies, interventions helped these students to solidify and connect their knowledge. As a result, the preservice teachers' understanding of the nature of science improved. It has yet to be determined whether they were later able to transfer that understanding to classrooms as practicing teachers. Another observation of these teachers revealed a separation of the nature of science as a concept from other science concepts. For example, when one of these teachers was going to include the nature of science in her/his class, she/he taught how science knowledge is discovered separately from the "regular" science content. In such a case, the process of doing science is taught as a separate subject. This example demonstrates how easily one aspect of science can be separated from other concepts and can cause problems for student learning.

Many studies examined experienced science teachers to determine their subject matter knowledge and its impact on classroom practice. In three of these studies, teachers were found to have alternative conceptions in science and communicated them to their students. (Atwood & Atwood, 1996; Klaassen & Lujnse, 1996; Lee, 1995) In many cases, teachers with the weaker content background had more incorrect ideas about science. An inadequate knowledge of science content seemed to be a primary barrier to the effective instruction of middle schools students (Lee, 1995; Cronin-Jones, 1991).

The teachers were not able to extend student conversations and discuss a topic in-depth with students because of their own lack of understanding of the subject matter. In a focused study, Gess-Newsome & Lederman (1995) found that not all biology teachers had a conceptual understanding of biology. Teachers in another study showed that their weak knowledge in science content was related to their heavy dependence on having students do individual written work from the textbook and their avoidance of whole class or group activities (Lee, 1995). Further, Arzi, White & Fensham (1987) found that the knowledge of science may not be sufficiently integrated across the science disciplines; therefore those ideas are not functionally available to the teacher. This notion is supported by another study by Abd-El-Khalick & Boudaoude (1997), which found that teachers might have a demonstrated competence in one dimension of knowledge in

science, but not in other areas. The ability to connect science concepts is lacking in many science teachers.

In a large-scale study of K-8 teachers in Scotland conducted by Harlen, Holroyd & Byrne (1995) in the eighties, the science knowledge of elementary teachers varied widely. In some cases, all teachers knew a topic, while in other cases no one knew it. Some later interviews did reveal some knowledge in those topics. More striking was that about 60% of the teachers, (about 13,400 people), expressed a need for help for a greater understanding of at least some aspect of their science background. About one quarter of the respondents (about 5,600 people) needed considerable help.

It is worth noting that none of the studies definitively expressed all of their findings, because the collection and analysis of personal ideas about beliefs is difficult in large populations. The findings from the smaller studies are not necessarily applicable to larger groups of teachers. It is difficult to ignore though, that the studies do present common patterns and results that help define a picture, that science teachers' ability to connect science ideas varies through the length of their teaching career. Experienced teachers were found to bring more declarative knowledge than novice teachers to their teaching (Gess-Newsome, 1999).

Teachers with stronger and more detailed conceptual knowledge of a topic see more connections and relationships to other topics, and can easily draw upon this knowledge in teaching and problem solving situations. However, these teachers are not immune to some of the same beliefs as inexperienced teachers. When experienced teachers are asked to teach out of their area, they revert to many of the behaviors and strategies used by inexperienced teachers (Gess-Newsome, 1999). In these studies it is shown that the experience of teaching is powerful and influences the teacher's development and use of content in the classroom.

Subject Matter Structure

Subject matter structure is easily confused with teacher's conceptual knowledge of science. The *subject matter structure* includes cognitive and philosophic knowledge of science representing the root ways teachers think about and know science. The

knowledge of science constitutes the facts and information (declarative knowledge), and the subject matter structure of knowledge attempts to identify an individual's private understanding of science's disciplinary structure and how it is then publicly presented (Gess-Newsome, 1999) as in teaching science.

Teachers have varied beliefs about how students should learn science content, which affect how they teach science. Although learning the origin of these beliefs remains a challenge for researchers, beliefs are often manifested in the ways science is taught. Warkentin (1993) conducted a comparison of middle school, high school, and college level science instructors' beliefs and knowledge of science. He found discontinuities in teacher beliefs about science knowledge across the various grade levels. Teachers of all levels agreed that science content was important, but that the ways they conducted their classes were quite different from each other.

High school and middle school teachers placed more value on the structured learning experience and used more worksheet completion activities than did college instructors. College instructors valued students' ability to use cognitive information processing strategies more than the secondary teachers did. These distinctions were apparent because the teachers believed that what they were doing was in some way best for their students. These beliefs may or may not be completely related to the content of science, but do affect pedagogy.

The level of content understanding that is needed for good lesson design is often not the same for all teachers. Klaassen & Lujnse found that teachers can argue with each other about lesson designs, because they themselves are not aware that they do not have the same understanding of an expression such as "to exert a force" (1996). These content discrepancies between teachers could contribute to inconsistent science instruction for students.

Teachers' coherent knowledge of science is important because it influences how their science content knowledge is translated into lessons. Preliminary findings on the conceptions of teaching science suggest that experienced science teachers consider a variety of learning experiences both in and outside of the classroom and bring to bear a structured, relatively coherent body of knowledge (Hewson, Kerby & Cook, 1995) to those experiences. Teachers with less content experience resort to simpler didactic

instruction, almost as a defense against students asking them to explain ideas. Carlson, who studied novice teachers, supports this observation, as he found that those with weak subject matter knowledge limited students' verbal participation in class (1987).

Nature of the Discipline

This category refers to the values and assumptions inherent in the development of scientific knowledge (Gess-Newsome, 1999) such as the ideas a teacher has about how the field of science creates new knowledge, the models of inquiry, and the way that evidence is used and interpreted to develop "scientific ideas". There has recently been a lot of research about the *nature of science* (Lederman, Schwartz, Abd-El-Khalick, Bell, 1999; Abd-El-Khalick, F., Bell. & Lederman, 1998; Abd-El-Khalick & Boudaoude, 1997; Lederman, Gess-Newsome, & Latz 1994; Pomeroy, 1993; Gallagher, 1991).

The review of the findings in this area of teacher knowledge and beliefs as they influence practice can be simply stated. "School science is still largely taught as if it were objective and value free, and theories are taught as facts (Cross and Price, 1996. p. 329). Unfortunately this position is a traditional view of science showing these teachers believe that science is static and objective, and that new knowledge is created through one scientific method (Abd-El-Khalick, Bell, & Lederman, 1998; Abd-El-Khalick & Boudaoude, 1997; Lederman, Gess-Newsome, & Latz 1994; Pomeroy, 1993.).

In a study by Pomeroy (1993) of scientists' and elementary and secondary teachers' beliefs about the nature of science, respondents were classified by their responses in three categories: 1. traditional views of science, 2. traditional views of science education and 3. non-traditional views of science. Scientists viewed science slightly more traditionally than did the elementary school teachers. The scientists had the most traditional view of science education, followed by the high school teachers and then the elementary teachers. More elementary teachers had a non-traditional view of science than both high school teachers and scientists. In another study, the majority of science teachers held traditional positivist views of science that emphasized scientific methods and the objective nature of science. These teachers devoted no time to teaching about the nature of science except in the introductory portions of their science text (Gallagher, 1991).

The nature of science. Even when teachers have been explicitly taught the idea that science is tentative, subjective, and can be conducted through several methods, they still do not teach this perspective on science to their students (Lederman, Schwartz, & Abd-El-Khalick, Bell, 1999). The connection among interventions to help teachers change their beliefs about the *nature of science*, and the resulting practice in their classroom has yet to be absolutely established. “Teachers, regardless of their level of teaching experience or background knowledge, have very limited formal preparation in the nature, history, philosophy, or sociology of their discipline. Without such a background, teachers carry positivist views of their discipline. They have the idea that science proves or disproves ideas, that science is completely objective and that scientists' ideas and presence are removed from what they are examining. This idea is translated into their teaching of science as a body of knowledge with an emphasis on vocabulary rather than as a balanced approach including the presentation of human and rule based knowledge generation, and the importance of cautious evaluation of knowledge claims” (Gess-Newsome, 1999. p. 19). This strong statement is evidence of the importance of research in this category of science teachers' beliefs and knowledge of the nature of the discipline.

Content Specific Orientation to Teaching

This category is focused on the instructional orientation of teachers, based on their beliefs about teaching and learning as they are grounded in a scientific discipline framework (Gess-Newsome, 1999). For example, teachers might choose to teach biology from a molecular, evolutionary or ecological perspective because that is their educational and personal belief background. The decision to teach a particular science is often based on the teachers' “orientation” toward the topic of biology.

The orientation of teachers' beliefs about their content understanding and teaching has been shown to influence how they teach science. In one study, Hasweh (1996, 1989) surveyed secondary science teachers and then categorized their views as either constructivist or empiricist. He related these views to their teaching practices. Teachers with constructivist views were more likely to use a richer set of strategies for instruction,

conceptual change models of learning, and to detect students' alternative conceptions of content than were their empiricist colleagues. These teachers helped students construct their knowledge rather than memorize it. Empiricist teachers were more likely to approach science objectively and as a static body of knowledge. Therefore, instructional strategies and approaches are evidence of an epistemological orientation in science of teachers' classroom practice.

The content background of secondary teachers also seems to influence how they prioritize content. Teachers with one strong topic background and a weaker background in other topics tended to teach the majority of the weaker topics more superficially than they taught their topical strength subjects. The weak topics sometimes received no more than thirty minutes of time throughout the entire school year. For most topics, the teacher's goal was only to expose students to the topic, not to assure that they understood it (Kennedy, 1990). This teacher-influenced adjustment in a science curriculum can also manifest itself in other forms. A study conducted with two science teachers by Cronin-Jones (1991), indicated that teachers significantly alter intended curricula to make them more congruent with their own teaching orientation and belief systems. As a result, the actual taught curriculum was very different from intended curriculum presented by curriculum developers or curriculum guides (Schmidt, et al., 1996).

A teacher's content background orientation is important. And "it appears that teachers develop implicit content specific orientations early in their careers, maybe as early as their own public school experiences. In fact, the more limited one's content background, the more likely one may be to rely on early classroom memories to develop an orientation" (Gess-Newsome, 1999. p. 21). Teachers' content knowledge and beliefs influence not only expectations for learning traditional content knowledge by students, but what the actual learning experiences are for the student.

Contextual Influences on Curricular Implementation

This category of *contextual influences and curricular implementation* includes the impact of outside factors on teaching science. These factors include: mandated materials, textbooks, curriculum guides, parents, students, and standardized assessments. These

factors may reinforce, challenge, or change teacher knowledge and beliefs (Gess-Newsome, 1999). This category looks at the link between the contextual variables in schools and teachers' beliefs and knowledge.

Many studies examined the behaviors of teachers as they related to the external environment. The findings reported in one case study by Cronin-Jones (1991) indicated that in addition to teachers' beliefs about their role in the classroom, about how students learn, and about attitudes toward curriculum packages, other types of teacher ideas also have significant influences on the curriculum implementation process. The findings indicated that teacher beliefs about the ability levels of students in a given age group and the outcomes for them exert powerful, and potentially negative or positive influences on the curriculum implementation process. Another study concluded that it is quite possible that "the ease with which a subject matter structure affects classroom practice (if at all) is as much a function of the relative complexity of the knowledge structure of the teachers' understanding as it is related to curriculum constraints, administrative policies, management concerns, and so forth" (Lederman, Gess-Newsome, & Latz, 1994. p. 144).

Another study stated that years of teaching science under these contextual influences could also shape teachers' views about science. Teachers may also restructure their understandings of the nature of science to fit the type of science that they have been teaching in school (Brickhouse, 1989). These findings highlight a confounding dimension to the task of examining teacher beliefs. External environmental factors influence teachers and their actions and they are difficult, if not impossible, to ignore.

To summarize, teachers adapt and adjust their teaching to their working situations. They generally use materials that match their views of teaching and learning, and if they can't choose their materials, they will modify them to match their personal perspectives (Gess-Newsome, 1999). The adoption of new curricular materials has to be closely monitored and checked with teachers' beliefs about learning and science. The nature of teachers' beliefs has a large impact on the implementation of curricular materials.

Teachers' beliefs can and do change over time. One study concluded that it is not reasonable to assume that teachers who have been in the classroom over a decade are acting on the same beliefs about science that they gained during their formal education.

Their philosophies of science are likely also to be influenced by years of teaching science in American institutions that often encourage control over creativity (Brickhouse, 1989). Experienced teachers hold tightly to techniques and methods that have worked well for them. Inexperienced teachers place much more faith in curricular materials, but often find themselves in conflict with textbook ideas (Gess-Newsome, 1999).

Summary and Recommendations

The relationship between teachers' beliefs and classroom practice is neither simple nor direct because of the many variables that influence the activities and the reasons for those activities in a classroom. The factors affecting what content is taught include concerns by teachers about student abilities and motivation, perceived pressure on teachers to cover content, weak content knowledge of teachers, classroom management and organization, inadequate resources and curricula, various instructional constraints such as space or facility access, and lack of teaching experience (Bell, Lederman, & Abd-El-Khalick, 1998; Adams, 1997; Cronin-Jones, 1991; Brickhouse, 1990; Kennedy, 1990). It is difficult and challenging to assess and draw precise conclusions about teachers' beliefs and knowledge. The categories of science understanding of conceptual knowledge, subject matter structure, nature of the discipline, content specific orientations to teaching, and contextual influences on curricular implementation help categorize teacher thinking, but don't yet lend themselves to a synthesis of research.

The research indicates that teachers' knowledge and beliefs are important and influence their actions. Currently not well defined is how each category of beliefs separately, and in what combination or sequence, actually influences classroom practice, and whether the combination varies for different people. As Brickhouse stated; "Teachers' knowledge and beliefs about the content, their role as teachers, how students learn, and the context of school are a part of a web of beliefs that influence one another" (1989, p. 6).

Given some of the limitations of prior research on teacher beliefs either through observations or interventions, there is a need for more careful and thorough examination

of specific types of thinking, the factors that influence the transfer of subject matter knowledge in the classroom, and the collection of that information.

First, a refinement in the assessment of SMS is needed. Researchers should assess aspects of teachers' SMS as well as knowing about the general influence of beliefs. Are there specific aspects of a teacher's SMS that have the greatest influence on their practice or interaction of those aspects? Much has been written about the positive influence of content understanding of teachers and student achievement. Researchers should probe the nature of that understanding and how it interacts with the pedagogy of a teacher in the process of developing her/his pedagogical content knowledge.

Another area of needed research is in the factors that influence the transfer of subject matter knowledge in the classroom from the teacher's thinking to how those ideas are presented to students. This area of research is about the ways that teachers interpret content for instructional purposes. As characterized by Schmidt, et. al. (1996), the teachers' intentional curriculum as determined by their interpretation of the curricular materials, and curriculum guidelines is important because teachers make changes to materials and guidelines to fit their biases and content interests (Gess-Newsome, 1999; Schmidt, et al 1996; Cronin-Jones, 1991).

A final area of needed research concerns the methodology for examining teacher beliefs and their influence on practices. Approaches have included interviews, classroom material collection, observations and various types of concept maps. These methods have been successful in gathering information for instructional materials and impressions from classroom observations. Less available are focused materials on specific aspects of science taught in the classroom. This could include the content and length of time for covering a topic, topics connected to the curriculum, topics introduced by the teacher, and finally the science being taught in relation to the stated curriculum that the teacher originally intended to teach.

Chapter III: Design and Method

The Design

The purpose of this study was to determine middle school science teachers' beliefs about the connectedness and coherence of science and the extent to which those beliefs affect their teaching of science. This study was a phenomenological investigation (Gibson, 1986), which attempted to define teachers' beliefs and knowledge about science using inductive qualitative research methods. The exploratory nature of this study required multiple instruments and processes for collecting data. The type of study design used previously for collecting data about teacher beliefs and practice in science (Martin, 1999; Van Rooy, 1999; Abd-El-Khalick, Bell & Lederman, 1998; Chen, Taylor, & Aldridge, 1998; Harlen, Holroyd, & Byrne, 1995; Cronin-Jones, 1991; Arzi, White, & Fensham, 1987), utilized primarily qualitative data collection and analysis. The analysis of the data was semi-structured (Maxwell, 1996), as the focus for the study was predetermined. Basic quantitative methods were used to collect data from a survey to identify potential subjects for the study.

The collection of data from a survey, two interviews, classroom observations, concept maps and classroom materials generated 204 pages of transcript notes and descriptive information. Copies of textbooks and other instructional materials used by the teachers were also obtained and analyzed. This data was used to develop a case study type description of each teacher including a theory about her/his thinking about science and its effect on teaching. Since the researcher's background is in middle school science teaching, and because it is understood that one cannot adequately study a subject matter outside one's area of expertise, middle school science teachers are the subjects of this study.

This chapter describes the process used to identify the subject teachers, the instruments used to collect data about the teachers, the materials collected from each teacher and the process for analyzing the data.

Subject's Identification

The subjects for the study included six grade 6-8 middle school science teachers. Because research suggests that teachers' understanding of the classroom situation and content they teach changes with experience, (Berliner, 1986; Grossman, Wilson, & Shulman, 1998), teachers with a range of experience teaching middle school science were sought.

In the winter of 2000, a survey was developed and administered to all middle school science teachers in Maine. A sample of teachers was sought whose responses indicated that they thought science was connected and coherent, and whose teaching assignments were geographically close to the researcher for the purpose of consistent observation.

After the surveys were returned, initial contacts were made with 12 teachers who met the criteria. In addition, these teachers had signed the survey with their name and a telephone number agreeing to volunteer to learn more about and to possibly participate further in the study. The next contact with the subjects was made by telephone. For each teacher, a full description of the study processes and her/his involvement and steps were discussed so that each had the opportunity to determine whether she/he was willing to participate in the study. Seven teachers stated that they were willing to continue.

In order to not sensitize the subjects to the study's focus, each was told that she/he would be interviewed and observed as a part of the study to determine the science she/he was teaching. In order to lower the teachers' concerns about being evaluated and to minimize the impact of the observations on the instructional content presented, no explicit reference was made to them about the study's specific intention.

Each of the seven teachers was again contacted in the late spring of 2000 by telephone. In this contact, the researcher requested one more confirmation of participation, allowing the teacher another opportunity for disengagement and requested names or titles of other people such as principals or superintendents within their school district who could also be contacted. The building level administrator was contacted in order to explain the intent of the study and to gain permission for the teacher's participation. In all but two cases, the superintendent was contacted to describe the study

and to request permission. This process resulted in the choice of seven teachers from seven different district middle schools in the southern two-thirds of Maine.

Because of unforeseen circumstances, one teacher dropped out after participating in the first interview. The remaining six teachers participated in all aspects of the study. There were three males and three females, with a range of three to twenty years experience teaching Middle School science. Two of the teachers taught at the sixth grade level, two taught at the seventh grade level and two taught at the eighth grade level. They taught in communities that ranged from rural and suburban in the part of Maine where three-fourths of the population lives. This sample of teachers is representative of gender, grade level and geography of middle school science teachers in Maine. For each teacher, a pseudonym will be used here to assure anonymity.

Each teacher taught in a public middle school with a population ranging from 85 to 106 students. Two of the schools were located in rural working class communities, two schools were located in middle class southern Maine communities, and the final two schools were suburban communities close to a major city in Maine. Details about the schools and communities are provided with the description of each teacher.

The Method

This study incorporated an inductive qualitative method of data collection and analysis, determining teacher beliefs about the science used in similar research (Gess-Newsome, 2000). The data collected was analyzed holistically to determine if any patterns or categories of ideas describing the teachers' beliefs about the connectedness and coherence of science could be found. These patterns and/or categories were then evaluated against other data from other instruments and processes used in the study. The patterns and categories for each teacher were then included or deleted depending on the consistency with the overall data available for that teacher. It was hoped that this method of analysis would remove potential bias and other intervening factors introduced by the daily activity of teaching in a public school. The detail of the analysis for each teacher will be provided within each description of the instruments and process.

Triangulation among data types was sought to confirm or question the evidence and to inform the research question of this study. The triangulation process also helped to develop a theory about the teachers' beliefs about science and how those beliefs impact their teaching of science.

The Survey

A survey was used to select the teachers for the study. All certified middle school science teachers in Maine were mailed the survey to assess their general beliefs, knowledge, and teaching practices. A total of 466 surveys were sent and 109 or 23.3 percent of the total were returned. After analyzing of a set of eight core questions about the definition, nature, connectedness and coherence of science, 12 teachers were identified as possible candidates to participate in this study. After contacting each and explaining the study, seven teachers agreed to participate.

The survey had four sections: demographics, beliefs and knowledge, instructional materials and participation in study. The demographics section asked the teachers about their gender, age, teaching assignment and content, and years of teaching. This information provided background information on the sample teachers. The beliefs and knowledge section assessed the teachers' beliefs about science. There were eight questions taken from the Views on Science-Technology-Society (VOSTS) survey (Aikenhead, Ryan & Fleming, 1989). The questions focused on the teachers' views about the nature of scientific knowledge and the nature of science. The instructional materials section asked questions about the type of curriculum materials they used, their influence and role in the classroom content coherence, and sequence of content. The final section of the survey was optional, allowing teachers to write their name and telephone number if they were willing to participate in the study.

The beliefs and knowledge section was used as the primary portion for the selection of the study teachers. The survey, called Views on Science-Technology-Society (VOSTS), was originally designed to assess student's knowledge of science and technology (Aikenhead, Ryan & Fleming, 1989). VOSTS has also been successfully used with university students and K-12 teachers (Aikenhead & Ryan, 1992). The items selected for this survey related to the nature of scientific knowledge and the nature of

science (the nature of observations, scientific models and classification schemes). They also addressed the issues of paradigms versus coherence across the various scientific disciplines (Abd-El-Khalick & Boujaoude, 1997). Analysis of the VOSTS can provide researchers with data to categorize participants' views into two areas, informed and naive.

"Views consistent with more recent conceptions of the nature of science advanced by such philosophers of science as Kuhn (1970) were categorized as informed. Alternatively, views were categorized as naive if they converged with conceptions advanced by logical empiricists" (Abd-El-Khalick & Boujaoude, 1997. p. 681). Because of the content, reliability, interpretation potential and wide use of this survey, it was chosen for this study as a good instrument for selecting teachers who say they believe science is a connected and coherent discipline.

In sum, twelve study teachers volunteered from the pool of teachers who met the profile from the analysis of this section of the survey. These teachers had had written their name and telephone number to be contacted for possible continuation in the study.

It should be noted that this quantitative data was collected for general descriptive purposes and was intended only as a means for identifying a pool of potential subjects for the study. No statistical tests were performed other than a descriptive comparison of numbers of teachers who responded to a particular set of questions. More rigorous statistical tests for comparisons among teachers would not be meaningful for this study.

Pre-Observation Interview

After the selection of the study participants, a pre-observation interview was conducted to gather background and teaching situation information for each teacher. A semi-structured interview of about one hour was requested and conducted prior to the start of the classroom observations. All interviews were conducted in the teachers' classrooms except for one, conducted at the public library in the town where she/he lived.

Prior to the interview, each teacher was reminded of the general intent of the study, the type of data that would be collected, and the time frame for the study. Each teacher was also reminded that the information collected as a part of this study would remain anonymous and would not be used for evaluation purposes as outlined by the

Lesley University Human Subjects guidelines. During the interview, the teachers were shown the audiotape recorder, which would be used for the interview.

The interview had three parts. The entire set of questions is located in Appendix E. The first part of the interview focused on the teachers' professional and academic backgrounds. The following questions were used as a guide for the first part of the interview:

What is your teaching load next year?

How do parents interact with you and the school?

What was the science teaching in your high school science classes like?

How did the science in these classes match your ideas of science?

What was the teaching like in your college science classes?

How did the science in the classes match your ideas of science?

When did you decide to become a science teacher?

What was it that helped you make the decision to teach science?

How well prepared do you feel you are to teach science?

What learning in science has provided you with the most confidence to teach science?

Have the recent state or national standards affected your teaching of science?

The second part of the interview focused on the teachers' beliefs and philosophy of science and science teaching. This included information on their intentions for teaching specific content, instructional materials and their views on the coherence of science. The following interview questions were used as a guide for this part of the interview.

If you had a philosophy of science, what would it be?

What are your specific goals for teaching science?

Do you have a curriculum? What do you follow?

What textbooks and/or supplementary instructional materials do you use to teach your students science?

Who makes decisions about what science is taught in your classes?

Do you believe that there is a culture or nature of science?

What is your philosophy of teaching science to your middle school students?

How do you feel your students learn science best?

Describe your teaching that helps them to learn science.

Describe teaching that makes learning science difficult for students.

How do the topics in your science classes fit into the overall science topic sequence for students in your school?

What are your students like?

In addition, three of the teachers were randomly selected to complete a Subject Matter Structure task. The procedure for using the task was slightly modified for middle school teachers from a similar task developed and used by Gess-Newsome (1992). This task asked the teachers to draw a visual concept map of the science they taught during the interview rather than take it home to complete and return later. The purpose of the task was to illustrate their thinking about the science they taught. The Subject Matter Structure task (SMS) was as follows:

> To try to understand your thinking about science as a discipline, please complete the following questionnaire.
>
> > What topics make up the science you teach?
> >
> > If you were to make a diagram of these topics, what would they look like?
> >
> > Have you ever thought about science this way before? Please explain.

After the three SMS tasks were completed, they were set aside. They were not examined until the conclusion of post-observation interview when all the teachers had completed the SMS task. The three teachers who completed the task in the pre-observational interview completed the SMS twice. A preferred methodological approach was to have one-half of the teachers complete the task twice and not examine them until these teachers in the second interview completed both diagrams.

First, the ideas the teachers drew in their diagrams remained open-ended, removing any possible researcher bias during the observations. Second, half of the subjects completed the task at the first interview in order to have a record of their thinking to compare with the second SMS task. This was done to determine if there was any effect on the teachers' thinking by completing the task. The task could have

sensitized the teachers to think differently about their science teaching and, in case that happened, this method would hopefully identify that effect. The SMS tasks were put away until after the classroom observations as opposed to examining them first and then using the classroom observations as another measure. Any pre-knowledge bias on the part of the researcher about the teachers' thinking was reduced by not knowing the teachers' thinking in their diagram.

In this interview, the teachers were asked if they had any questions about the next step of the study and the use of the interview data. This was done to reduce the concern by the teachers about the study process and to assure them that this process was confidential. Each teacher was told that there were no right or wrong answers to the interview or task questions. The questions were intentionally vague.

The pre-observation interviews were audiotaped and later transcribed. Any additional information such as copies of textbooks, teacher manuals or other information about the content to be taught was collected and documented. As stated earlier, the SMS task diagrams were put away until the conclusion of the post-observation interviews.

The information gathered in this pre-observational interview and from other classroom materials was primarily used to create a background description, (i.e. classes taught, how many years in the school, school situation and school responsibilities) and an academic summary (i.e. courses taken in preparation to teach, current learning practices and other professional interests) for each teacher. The quotations provided in this document have been edited to provide illustrations of the points and ideas of the teachers. Additional information about each teacher's philosophy and beliefs about science and her/his science teaching were used to enhance the data from the final interview.

Classroom Observations

Classroom observations were included in this study design to collect information about the science that the teachers actually taught. The method for collecting this data included recording the science being taught in the teachers' classrooms, and collecting classroom materials, lesson plans and artifacts. The purpose of the classroom observations was to record the actual science content taught or what might be called "topic coverage". The method used to collect this data was developed specifically for this

study. The data collection instrument and protocol provided good quality data on the science content that the teachers taught and reduced the researcher's bias by providing an objective instrument and protocol. A full description of the instrument will follow.

Planning and conducting the observations

The classroom observations were prearranged with each teacher. The scope of the observations was to visit the classroom no less than ten class periods within a three to four week period. It was important to be able to observe the sequence of activities in an instructional unit to document the content flow in the unit and any connections that the teacher made within that unit. An assumption of the researcher was that the sequence of activities in an instructional unit represented the teachers' beliefs about how and what to teach to their students in that particular content. Therefore, it was important to be able to observe at least a single instructional unit from beginning to conclusion.

Observations were scheduled with the same class of students and during a specific unit of study chosen by each teacher. The best days for observation were discussed several times over the period of observations. Each teacher was observed for a minimum of nine hours. A total of 56 separate sessions or 65 hours of observations were conducted. It was intended that the observations would occur during at least one instructional unit; this was accomplished with all teachers except one. For three teachers, the researcher observed one instructional unit and part of another. Because of the distances to the schools, integrated thematic units, daily rotating block schedules, early release days, vacations, snow days and teacher absences, the observations sometimes overlapped with other instructional units. When the researcher observed more than one instructional unit, the classroom observation data was still included because the data represents the topics presented to help the student learn science.

The reason that this data is believed to not affect the results of this study is that the observations were designed to record the teacher's intended content presented in the classroom. A change from one instructional unit to another, or breaks in the instructional sequence do not necessarily affect whether the teacher makes connections or presents science in a coherent fashion. The science presented by the teacher was intentional, and the observational instrument collected this intentional content. Only after the data was

analyzed were judgments made about whether the content was connected to other science areas. The observations took place as often as possible so as to be able to view the sequence of science covered in an instructional unit. To assist in the analysis, no judgments were made about what was science being taught until other information about the instructional unit was assessed.

Many types of classroom interactions and activities were included as data and recorded, except for classes that tested students throughout the class period. Attending only some classes, such as only highly interactive classes would bias the observations toward those classes; and, classes that the teacher might use to make connections to other science ideas would be potentially left out. The purpose of including all class activities is that the classes represent the sequence of science that the instructor is teaching. Each block of time is deliberately used by the teacher whether active or not, and the class represents the interpretation for learning through the teacher's beliefs about the particular science content for that instructional period. It also provides data about whether the teacher makes connections to other science topics resulting in being able to make statements on the coherence of the science content for that topic. Therefore an observation could include lab experiences, movies or library research.

Instrument and protocol development

The researcher developed, piloted and used an instrument and observation protocol to record the science content used during a class period. The Project 2061 Benchmarks (AAAS, 1987) were used as the referent for science content topics by the observation instrument because its 13 broad categories allow for identifying and distinguishing between science content topics. The Benchmarks articulate science content topics in a way that seems inclusive of all possible science content topics, thus the identification of connections appeared easier to the researcher. Some examples of the spectrum of topics in the Benchmarks are the Physical Setting, the Designed World, Common Themes, and the Human Organism. The Benchmarks allow for examination of the coherence of content and they are also able to identify the sub-Benchmark content specifics, grade level grouping, and research supporting the learning of a science concept.

The National Science Education Standards (NSES) were not used in this study as these standards categorize science in a more traditional manner such as Life, Physical and Earth Sciences. This grouping limits possible science content to three categories instead of the 13 Benchmark areas so the connections within science are more difficult to articulate. The NSES do share 80 % of the Benchmarks so there is consistency between the two documents for content. However, the difference between the two documents was great enough to affect how this study could identify how science concepts are articulated and connected. The observation instrument, (Appendix F), lists all of the 13 Benchmarks and their sub-Benchmarks.

The observation protocol developed for the instrument allowed for recording the substantive content presented in the classroom. The instrument was used only to document the science content presented in the classroom. Other documents such as lesson plans, instructional materials, and teacher interviews were used in the analysis process to assist in determining the content of the instructional unit, identifying connections to other areas of science and helping to decide on the degree of coherence of the science presented.

The researcher piloted the instrument in two different teachers' classrooms prior to use in the study to develop a protocol for use with the instrument. The goal of the pilot was to determine if the instrument could collect the science content presented in a class. This ability was validated after the two trials. However, a time interval for collecting the information was needed to collect only the substantive science content and not the non-instructional comments or short diversions. It was an attempt to make a distinction between classroom banter and the intended instructional content, in order to measure the classroom lesson content. After trying several intervals, the interval of two minutes was established as an appropriate time period for recording the science content topic taught.

The two-minute interval was found to be the most effective in recording the content of science as it excluded brief topical asides by teachers, such as comments about other topics, or responses to student questions unrelated to the day's lesson topic. However; if the teacher spent at least two minutes on the topic, then the topic was recorded. This amount of time was judged as significant as the teacher would have

intentionally had to decide to use that time in her/his lesson or through an adjustment to incorporate the topic.

The intentionality of the teacher's handling of a topic is important, since it relates to the teacher's beliefs about presenting that science topic, and is representative of the translation of content into teaching. Periods of non-instructional time during an observation were not recorded, as science was not being taught. No judgment was made with the observation instrument about whether the teacher's instructional method was consistent or of good quality.

The instrument recorded the substantive science topics for a class period, and then provided information that could offer a perspective on whether the taught science topics were connected to other science areas. The record of science content taught in a classroom was examined for any connections to other science topics. Using the stated instructional materials and the Benchmarks, any connections to other science content topics in the class period were then identified as a part of the teacher's stated or unstated curriculum.

The instrument didn't document the ways teachers think about science in their preparation and presentation of science, instructional methods, lesson effectiveness or the quality of the interaction between the teacher and students in the classroom. For this study, the pertinent information was the science being taught in an instructional unit.

Method of Analysis

Once the classroom observations were completed, a review of the instructional materials was conducted and then cross-referenced with findings from the classroom observations. The analysis of this classroom data included an identification of the science taught, a determination of any connections among science topics and whether the science taught was coherent. To accomplish this, the instructional materials were examined to identify the stated content for the instructional unit. These materials included lesson plans, textbooks, resource materials, handouts, laboratory activities and other artifacts related to the instructional unit. The recorded science content for each teacher was then matched to the appropriate Benchmarks. A comparison was made between the stated curriculum, the instructional materials, the observed curriculum, and the recorded

science, to determine the stated and unstated curriculum for each instructional unit for each teacher. Another category of records from the classroom was created to identify the content that fit the Nature of Science, Common Themes and Habits of Mind Benchmarks.

In this study, the stated curriculum is the one that the teacher had planned either through the development of her/his own instructional materials or from commercially developed materials or some combination of both. This stated curriculum was found in textbooks or inferred from the teacher's written lessons plans and student materials. The non-stated curriculum, in this study, is any science content that is not explicit in any of the materials provided by the teacher or stated by him/her in an interview.

The last category for analysis has three Benchmarks areas: the Nature of Science, Common Themes and Habits of Mind. These three Benchmark areas are inclusive of the process of science, how science ideas are developed, scientific inquiry, and how scientists communicate science. This science content was sometimes a part of a teacher's stated curriculum, but most of the time these ideas were expressed in the interviews by teachers rather than found in the instructional materials. These science topics were separated out for the analysis because they represent often implicit science content and are foundational ideas for the definition of science, how science is conducted, where and how ideas in science arrive and the communication of science. These categories represent significant aspects of science content. A determination by the researcher was made to separate them out to further identify what science was being taught in the classroom and how often to identify coherency. They are also important in helping to develop a theory about whether the science presented by a teacher is coherent.

The analysis created four possible descriptions of science being taught. None of these descriptions is exclusive, as all of the teachers included aspects from each, but the teachers tended to exhibit one type more than another. One type of description shows a teacher who taught only what she/he said she/he was going to teach. This teacher strongly sticks to her stated curriculum and makes few connections to other areas of science. This teacher might be presenting science in a coherent fashion as related to the instructional unit.

Another example is a teacher who does not teach her/his stated curriculum. She/he may be observed making connections to other areas of science, which are not

necessarily consistent with the stated curriculum. This teacher would be teaching in a non-coherent fashion. A third description is of a teacher who instructs mostly from the Nature of Science, Common Themes and Habits of Mind Benchmarks. This teacher was seen as making connections to these Benchmarks, but not to other science content. A final description type was a teacher who teaches with a thoughtful balance between the stated curriculum, the Nature of Science, Common Themes and Habits of Mind and the non-stated curriculum. This teacher made relevant connections to other areas of science in order to make the science more coherent. Developing a coherency within science is important to this teacher. Making connections within science adds to the idea of a coherent science program.

To identify these four types of teacher descriptions, two aspects had to be examined: 1) the type of connections made, and 2) the coherency of the science. The first aspect examined included an analysis of the type of connections and was conducted by looking at the number and location of recorded marks for the various content areas on the observation tool for each teacher. A determination was also made concerning the content of the stated curriculum by reviewing the instructional materials. All of the marks were then sorted into three categories: stated curriculum, non-stated curriculum and the Nature of Science, Common Themes and Habits of Mind. A final analysis was conducted by comparing the similarity of the connections to the Project 2061 Atlas (2001) connections of science ideas. The Atlas was selected as a reference since it used the Benchmarks as the basis for identifying science content and is a research-based analysis of science concepts showing how they are connected and related across and within Benchmarks. This analysis provided the number and type of connections for each teacher.

The second part of the observation data analysis examined whether the teacher addressed the science ideas coherently. For this study, coherent science means science that represents the knowledge and skills presented, along with other ideas that are related to it, helping a learner build a conceptual framework to understand, retrieve and transfer that knowledge (Nelson, 2001). To show this for these teachers, a comparison was made of the science topics presented, connections made, and whether these ideas were a part of the stated curriculum. This helped indicate whether the teacher was building a framework of ideas for students.

This analysis included looking at the connections made within the general Benchmark category. For example, the science presented by the teacher may have included other science topics within the same Benchmark category such as the *structure of matter* and *motion* in the Physical Setting Benchmark. This type of topical inclusion might indicate coherency of content depending on the other content the teacher presented because the teacher was staying within a larger framework of ideas. Another possibility would be a teacher presenting topics found in other Benchmark categories such as the *structure of matter* and *cells*. *Structure of matter* is a topic in the Physical Setting Benchmark and *cells* is a topic in the Human Organism Benchmark. This type of topical connection might indicate incoherency if the teacher was not making a direct connection. It also might indicate coherency of the science if the topic of molecular structure was a part of the stated curriculum on cells. The use of data from the observations in the classroom along with the stated curriculum was critical in making a determination of whether a teacher presents science in a coherent fashion.

From this analysis process, a science content table was generated for each teacher illustrating her/his science "topical coverage" and the coherence of the science within a Benchmark category (Table 3).

Table 4: Recorded Science Content Example Table

	Number of recorded observations of a Benchmark	**Number of areas within those Benchmarks and the number of those areas.**
Nature of science, common themes, and habits of mind	66	10 of 13
Other stated content curricular Benchmarks	116	4 of 6
Non-stated curricular Benchmarks	55	9 of 24

The table for each teacher provides a picture of how the science content is taught in that classroom. The locations of the observation marks define the science taught. Each teacher had a different distribution of marks. A closer examination was then made of the actual stated content for each teacher. For example, if the teacher was teaching cells, she/he would most likely have most of her/his recorded marks in the Human Organism Benchmarks forming a cluster. She/he could also have had many marks in the Nature of

Science, Common themes and Habits of mind category if she/he had had an inquiry-based classroom. This would show up in the chart as a relatively high number of marks in that category. Finally the deviations from their stated curriculum would determine how many marks would appear in the non-stated curriculum category. The number of marks in the Benchmark portion of the chart indicates the emphasis of the teacher toward the three categories.

The intentionality of the teacher to teach particular topics and their sequence illustrates the influence of the teacher's beliefs about teaching science, and the connectedness and coherence of science in her/his classroom practice. Several interpretations are possible from the data in the science content charts. They include the following: the extent to which the teacher is focused on the stated curriculum, whether the teacher connects science ideas, whether she/he incorporates the Nature of Science, Common Themes and Habits of Mind aspects of science, the coherency of the science presented for that unit, and the amount of instructional movement into science areas other than the stated curriculum.

Three types of teachers characterize possible results from the analysis.

Type I Teacher: Singularly content focused. A positive indicator for a teacher being singularly content focused would be a high number of records for the stated content curricular Benchmarks. This type of teacher would teach a topic such as structure of matter and use atomic models and worksheets to teach the structure of atoms and chemical variations. The teacher would not include activities that might demonstrate characteristics of matter or have students asking questions about why there are differences in characteristics through their exploration with different materials or combination of materials.

Type II Teacher: Content curricular and makes connections. For this type of teacher, it is also possible to be curricular content focused with connections to other areas of science. They would have a relatively high number of marks in the sub-Benchmarks group. This pattern would indicate that the teacher presented a variety of science topics but that he limited them within the larger Benchmark category. This might indicate a coherence of science by making connections within a larger category, but not into potentially unrelated science areas.

Type III Teacher: Unfocused on the stated content. These teachers exhibit low number of records in the stated content curricular Benchmark and within that Benchmark. This would indicate that they were focused on other areas of science and were unfocused on the stated content curriculum. This would indicate incoherent teaching as the teacher was covering many topics not stated and the topics may not be curricularly related.

The second category of science content area is the foundational ideas in the Benchmarks of Nature of Science, Common Themes and Habits of Mind. These Benchmarks represent a definition of science, how ideas in science are generated, what science ideas cut across all of science, scientific thinking, and how to express and share ideas in science. These areas of science help to define the coherency of science within and across science concepts. Having a high number of records in these categories and stated curricular areas could indicate instruction with a strong foundation in the Nature of Science. A combination of both the Nature of Science, Common Themes and Habits of Mind category and the stated curriculum would demonstrate connections between science information and how those ideas are generated and used. This could be an example of a more coherent and connected science curriculum.

Another kind of Type III Teacher might have a high number of records in the nature of science categories relative to the other content areas. This could potentially indicate instruction characterized by being mostly “process”. An example could be a unit that is focused only on scientific inquiry and not inquiry about a science topic. A teacher could also exhibit teaching practices so she/he has a low number of records from the Nature of Science, Common Themes and Habits of Mind Benchmarks. This could indicate a fact-based curriculum with little time spent on how science ideas are generated. It might also indicate something more complex, such as issues related to the specific unit, the amount of materials available or other general teaching factors, such as if the teacher had no instructional materials and taught the topic in a limited fashion. That unit might not be characteristic of how the teacher normally teaches science when she/he has adequate instructional materials.

The third category of marks recorded in the classroom observations is the non-stated curriculum. These topics identified would not have appeared in any written or anecdotal materials collected from the teacher, but used in the classroom. For example, a

teacher might be teaching about fossils and in the process learn that her/his students do not understand how scientists determine the age of fossils. The teacher could then decide to spend the rest of the class period teaching about carbon dating as a method for telling the age of rocks so that students might have some basis for understanding how scientists determine the age of fossils. Atomic decay was not a part of the instructional unit as stated, but the teacher made the decision to take class time to focus on that topic.

A high number of records in the non-stated curriculum category could be indicative of an unfocused and incoherent curriculum. It might also represent a connected curriculum, but one that is not connected in a coherent fashion. A teacher with low numbers of records in this category would indicate that the teacher has a focused curriculum and does not connect her/his topics to other areas or science. This category of non-stated content represents apparent deviations by the teacher from stated curriculum. The intention of the teacher to spend time on these topics is difficult to determine, but recording the amount of time spent on the topics in class validates the teacher's inclusion of the material in class.

In the analysis of these three categories, a review and comparison was made of daily curricular and teacher-provided materials to identify the stated curriculum. The comparison between the stated curriculum and what was recorded in class allowed for the determination of the category in which the recorded marks were placed. The observation tool does not determine whether the connections are useful, but rather what science was presented and how the science is related within the Benchmark framework.

After the classroom marks were placed in the three categories, an examination was conducted of content taught and whether it was connected and coherent based on instructional materials, teacher interviews, and the Benchmarks. This analysis was to determine the level and extent of the connections a teacher made and whether this set of ideas was coherent. The number of topics presented by the teacher within and across the Benchmark categories was examined. A topic present but not a part of the stated curriculum potentially represents the intention of the teacher to connect the topics of science. The teacher had decided to take the time to include that topic and not others. Each Benchmark has sub-Benchmarks that help describe the range and scope of ideas under that Benchmark (Table 5).

Table 5: Two Benchmarks and Related Subtopics

Benchmark	Sub-Benchmark
Physical Setting	The Universe
	The Earth
	Processes that shape the Earth
	Structure of Matter
	Energy Transfer
	Motion
	Forces of Nature
Human Organism	Human Identify
	Human Development
	Basic Functions
	Learning
	Physical Health
	Mental Health

A topic connection made by a teacher within a Benchmark is a different type of connection than those made to other Benchmarks. Connections within a Benchmark would represent a more closely related connection than one across Benchmarks. For example, using the Benchmarks as the categorical system for science ideas, connections in the context of a roller coaster among *motion* and *forces of nature* sub-Benchmarks is more closely related than a connection in the context of skeletal movement between *motion* and the *basic function* sub-Benchmarks from the Human Organism Benchmark. The science concept of how something moves would be the same, but the context for the connection made is found across two Benchmarks rather than within a Benchmark.

To help determine the coherency of such connections, the researcher used the Project 2061 Atlas (AAAS, 2000) as a reference. If the number of marks for a teacher within the Benchmark category is high - such as in a unit on physics - and the state curriculum was about *motion*, *waves* and *molecular movement* within the same instructional unit, this teacher connected several science topics within a Benchmark category. This represents a high level of "within Benchmark" connections and a low level of "across Benchmark" connections.

This example could represent a curriculum that is coherent but is not very connected. It also might represent something more complex related to the science concept itself. Some science topics are more easily connected than others. Another example can be seen with a teacher who made many connections across Benchmarks and not within a

Benchmark. This would represent a curriculum that was connected, but not necessarily coherent. This type of analysis was needed to determine the connectedness and coherency of the curriculum.

The Project 2061 Atlas was used only as a basis for determining coherency, as the Atlas is based on the previous work used in this study. It is not the only way to make this type of distinction. The recording of science topics within and across the Benchmark categories was examined closely to determine the intent and level of coherence of the science being presented within the discipline of science.

An aggregate science content chart for all six teachers was created for generating a general hypothesis from each teacher's chart and one for middle school teachers' beliefs about science and science teaching as found in the research questions for the group of teachers. This is discussed in the Chapter VI.

Documents and Anecdotal Data

Documents used in the normal course of teaching were collected as another source of data about science taught in the classroom. Teachers were asked to provide instructional materials, worksheets, textbooks and other primary reference materials used to help design and teach the lessons. These documents were collected, filed with the observation forms and noted on the researcher notes as to the sequence of topics and their use. This included classroom notes and any comments the teacher made about the materials.

The analysis of these documents was conducted separately from the analysis of the transcripts. There were two primary reasons for the collection and analysis of these documents. The first reason was to provide information about the content of the classes that was not observed. These classroom materials provided additional information about the content and hopefully confirmed what was seen in the classroom observations. The second reason was that these materials could be used to further identify the teachers' beliefs about science as well as the extent and importance of the connections made in the classroom. They could confirm or show the rationale for the amount of time spent on a science topic.

For example, spending time on the topic in the classroom, but not finding the topic in the classroom materials could indicate that the teacher didn't think the idea was important enough to include as a curricular topic. They might have made an on-the-spot decision to include it in class or the teacher might have unintentionally wandered from the stated curriculum.

The analysis of classroom documents followed the classroom observations and was done separately for other data types. The materials were examined and placed in chronological order of use, then compared with the classroom observation instrument. Also a comparison was made with the order of the materials and the Subject Matter Structure task topics to determine patterns of sequence. Any discrepancies or congruence with what the teachers said they taught in science were noted.

For each class observation, the researcher took anecdotal notes. These included classroom activities, sequence and connections between classroom topics, student attitudes, length of time on a particular task, wall decorations and other general descriptive elements of the classroom and the students as possible additional indicators of the teachers' beliefs about teaching science.

For example, in one classroom, there were student-constructed cell models displayed around the classroom. During this teacher's classroom observations, she never used or referred to the models. This was noted and then asked about later as a part of the post-interview questions. It turned out that the models constituted an earlier assignment. The teacher then explained in the interview her beliefs about the sequence of lesson topics and why she gave the cell models assignment prior to the student activities observed by the researcher.

These notes were analyzed separately from other data types and followed the classroom observations. The notes were in chronological order and were compared to the classroom materials used in the observations. Any discrepancies as well as congruence with what the teachers said they taught in science were noted. This anecdotal data contributed to the stated philosophies and ideas expressed by the teachers. It also provided another source to help narrow in on the connectedness and coherence of the science that the teachers taught.

Post-Interview

This method for data collection was an audiotaped semi-structured interview lasting for approximately one to two hours, and occurred within three weeks of the classroom observations of all the teachers. One exception occurred when an interview was conducted twice because the quality of the original tape recording was too poor to transcribe. The second interview for this teacher occurred about six weeks after the classroom observation.

The post interviews occurred after an analysis of the pre-observation interview and the classroom observations data. These interviews were designed to focus specifically on the teachers' beliefs about the potential for connections and coherence in science and whether they actually make these connections for their students.

Each interview, except for the one that had to be repeated, was conducted at the teacher's school at the end of the day. They were again reminded of the general purpose of the study and the information that this interview would provide. They were assured that the material in the interview would remain confidential and that their identities would be anonymous. The researcher reminded the teachers that it was the science that they were teaching and why they taught particular topics when they did that was of interest to the researcher, not how they taught the science.

The first part of the interview focused on questions that would remind the teacher about and clarify aspects of the lessons observed. These questions helped the teachers refocus on the lessons, explain their sequence, and provide more information about the lessons. It was hoped that these questions would raise the teachers' comfort level by focusing on what was taught during the observations, and would help them be more open-minded during the rest of the interview (The interview question form is in the Appendix G).

The opening questions asked about the lessons and unit they taught:

Which units/lessons do you think were the most successful?

What should students know/be able to do now as a result of your teaching this unit? What minimum would you be happy with? What would be the best possible outcome?

What influence did my being in your classroom have on: Your students? Your teaching?

The next part of the interview focused on gathering data on the teachers' rationale (intentions vs. reality) for the teaching of science. The questions targeted the aspects of the classroom that might facilitate or limit the teaching of science. Any perceived situational constraints were of particular interest as they affected the teachers' practice. The questions were:

Why were the observed lessons/units taught in this order and manner?

What advantages/disadvantages do you find with this sequencing?

How do you determine the length of time you spend on a topic?

Is there science you would like to teach as a part of this unit? What were the limitations that prevented you from including those science ideas?

Do you plan on making any changes in this unit for next year?

If given total freedom, would you change your teaching of science? How and why?

The next part of the interview focused on how they teach science. The purpose of these questions was to establish an instructional philosophy as it relates to the teaching of science. These questions are important as they outline the thinking of the teacher about the planning and construction of units and her decisions about the instructional approaches to teaching science. It was hoped that this set of questions would help identify the teachers' beliefs about the purpose of materials and of teaching science and would add to the data on the teachers' science subject matter framework for teaching.

You described earlier that you have an undergraduate specialization as ____.

Does this area of specialization affect the manner in which you teach science and other topics in science?

Why do you teach the way you teach?

What criteria do you use in selecting these materials?

On what basis do you prioritize materials/activities when you have more material than you have days in a unit?

What role do text-provided materials play in your teaching? Your thinking about teaching science?

The next set of questions in the interview focused on the influences on the teachers' beliefs about the nature of science and whether science is a connected set of ideas. One question asked about academic background and its influence on their teaching. Another two questions were identical to questions on the original selection survey used to identify the sample of teachers. The possible answers to these two survey questions were reduced to two choices from the original four possible answers.

The researcher wanted to force the teachers to select one response that clearly delineated whether they believe science is a connected discipline or not and to ascertain if teaching science in a connected fashion facilitates or hinders the learning of science by students. The purpose for asking questions twice was to provide a check for the reliability of the questions in this survey, and to measure whether the teachers' beliefs were constant during the period of the study. It was important to determine whether participating in the study influenced the teachers' beliefs, and to determine whether their thinking was consistent over the study time period. The repeated survey questions are as follows:

How do you react to the options for answers for the following statement from the survey I asked earlier: Statement: *Some educators have suggested students will better understand science if they first grasp certain fundamental concepts applicable across science areas. (Select one)*

1. It is best to have students learn separate components of science (such as cellular structures in biology) and have an opportunity to apply the separate ideas in new situations as an assessment.
2. Is it best for students to learn science through connecting science concepts in different contexts such as the flow of energy in ecosystems and photosynthesis as they build knowledge about the discipline of science.

How do you react to the options for answers for the following statement from the survey I asked earlier: *Science is an ever-changing discipline. Scientists are learning more and more about the world. This causes them to often focus on narrower and narrower aspects of science. This may impact students' science learning. (Select one)*

1. Students should be exposed to the variety of new science learning in the multiple areas of science, but focus in the areas such as Biology, Chemistry and Physics.
2. Students should focus on an aspect of science at one time while the teacher illustrates connections to other science areas such as biology, chemistry and physics not studied at that time.

The next aspect of the interview included the Subject Matter Structure (SMS) task. SMS task asked the teachers to draw a visual illustrating the curriculum they taught (the complete task is in Appendix E). The SMS task was designed to contribute to a fuller understanding by the researcher of what the teachers believe about the science they teach. After they completed the task, they were asked to respond to the following questions:

Describe in words what you have written on paper.

How did you select the topics, and did you exclude any?

What do the connections between your topics mean? (if appropriate)

What specifically do you mean by (use a term from the paper)

If I substituted one term for another (for instance, animals for zoology), would these two terms convey the same idea? Why or why not?

Are these topics you listed of equal scale or magnitude? Please explain.

What are the most important content topic/themes that you think should be emphasized in science?

Are those important topics/themes listed as a part of your diagram? Why or why not?

Would these topics/themes fit and/or be appropriate in your diagram?

Is there a sequence to the topics you have in your diagram? Why and why not?

Although three of the teachers had completed this task in the pre-observation interview, they completed the task again. The SMS task for those teachers was repeated to record whether the participation in this study influenced the thinking of the teachers. A comparison of the two SMS tasks was done: one prior to observations and the second SMS done after the observations were made and any inconsistencies or congruence noted. For these teachers, an additional set of questions was asked to identify whether drawing the diagram influenced their thinking about science or science teaching.

Have your views changed about science from when you first completed this diagram at the beginning of the study? If so how and why?

Did the act of completing this SMS form at the beginning of this study have any influence on how you have filled it out now? On your teaching?

Do you think the structure of the content you provided in the diagram is evident in your classroom teaching? Why or why not?

The final part of the interview focused on the idea that science as a discipline has concepts that are connected to each other, even though they may be categorized in different areas of science. These questions intended to help the teachers articulate their beliefs again about this idea of the connectedness of science. The questions are as follows:

National and State standards and some scientists recommend that science should be taught by integrating aspects within the discipline and making connections to the world. Is this is a reasonable task for middle school science?

How successful do you think you were/are in doing so in the unit I observed?

(If needed). What are the things that limit you from integrating the ideas and making connections?

What might you change if you could about the life, physical and earth science categories of science?

Have you ever thought about science with those types of categories or changes? Why or why not?

The data from the post-observation interview was used to help describe the teachers' beliefs about science and science teaching. By asking them specifically about their practice and by forcing responses to specific questions, it was hoped that this would lead them to a better understanding of their beliefs and how these beliefs influence their classroom practice.

Triangulation of Data Types

All separate sources of data and the results from each instrument were considered separately first and then together in an effort to make discrete judgments about each teacher, and then to determine the overall congruence of the data to answer the original research questions. For example, if a teacher talked in the first interview about science being a connected discipline, that statement was judged against what actually happened in the classroom observations, the curriculum and instructional materials used, and the teacher's SMS task diagram. Any examples of confirmation or contradiction were noted and are discussed in the teacher profiles in Chapter IV.

After developing a profile for each teacher, an aggregate was developed for the teachers as a group. This was done to see if a more general statement could be made about these middle school teachers. The triangulation of data was used to help answer these four research questions:

1. Do these middle school science teachers believe that science as a discipline, is a connected and coherent field of study, or is it comprised of separate areas of study?
2. How does their imposition of knowledge and beliefs affect the effectiveness of curriculum materials at the first levels of the TIMSS tripartite model of curriculum?
3. Does the belief about the coherence and connections of science impede or facilitate effective science instruction?
4. Is there a testing effect when attempts were made to assess their specific beliefs about science as a connected and coherent discipline?

The first question, *"Do these middle school science teachers believe that science, as a discipline, is a connected and coherent field of study, or is it comprised of separate areas of study"* addresses the teachers' beliefs about science. The teacher-generated materials were analyzed in several ways to answer this question. General trends and consistencies were identified from interview data about the teachers' stated beliefs about science. The classroom observation data was used to document which science was translated into their teaching by recording the science taught in the classroom. The SMS task was used to identify similarities and differences in the teachers' stated beliefs and in classroom observations. This information was compiled into a profile where congruence or discrepancies between and among the data sources were identified for each teacher. Other data types, such as instructional materials and anecdotal notes, were used to enhance the interpretation of the data in an effort to better understand the teacher's intent in teaching science.

In addition, the SMS tasks were analyzed for similarities and differences in content, organization and rationale as compared to the SMS stated in their interviews. Potential reasons for any differences and similarities were sought in the individual profiles. This assisted in the generation of hypotheses that would explain patterns in each profile.

A final check was conducted on the SMS task itself. A broad examination of the teacher's SMS task results was conducted to identify key ideas. This analysis was used to compare the results of this study's SMS task data collection procedure with similar approaches in other research. If stark contrast existed with the ideas drafted by the teachers in this study and those provided by teachers in other studies, it was considered evidence of a lack of validity of the instrument used in the other studies and a partial validation of the procedure used here.

The second question, *"How does their imposition of their knowledge and beliefs affect the effectiveness of curriculum materials at the first levels of the TIMSS tripartite model of curriculum"*, addresses the extent to which the teachers' beliefs about science influenced the stated or required curriculum. An examination of the teachers' curricula and instructional materials with the teachers' stated beliefs from the two interviews helped develop hypotheses concerning the extent of the influence. Hypotheses

concerning teaching load, the role of the textbook, access to instructional materials, involvement in other curriculum development work, academic background and years of teaching were explored. Broader comparisons were also made among teachers to test the hypotheses.

For example, if teachers stated that they thought the role of the textbook was ancillary to their planning of science content and instructional sequence of content, specific accounts of this were sought from the classroom observation and lesson plan analysis. The identification of examples either confirming or discounting the use of the textbook encouraged the development of hypotheses about the translation of the teachers' beliefs about the connectedness and coherence of science, the role of the textbook and their classroom practice. Other factors were examined such as years of experience or other curricula work to assess the possible influence of those factors on this situation.

The third question, *"Does the belief about the coherence and connections of science impede or facilitate effective science instruction?"* addresses whether the teacher's stated beliefs about the connectedness and coherence of science impede or facilitate effective instruction. Beliefs about the connectedness and coherence of science were provided through the interviews and the SMS tasks. An overview profile was developed for each teacher through a global analysis of the data. These profiles were built for each teacher based on what they stated and then did in their classroom. To determine whether these beliefs impede or facilitate effective instruction, a comparison was made between the derived belief theory for each teacher, and the classroom observation record of science content. The classroom observation data provides the number and type of connections made by the teacher leading to a lesser or greater coherence in the classroom. High congruence between beliefs, the intentionality of the teacher in the classroom and her/his approach to science indicated a direct relationship between a teacher's beliefs and practice for a connected and coherent science instruction and more effective teaching. Limited congruence was taken to imply a complicated relationship or no relationship at all. These relationships were also used for all the teachers to generate a more general hypothesis about the potential importance of teachers' beliefs about science and their impact on effective teaching.

The final question, "*Is there a testing effect when attempts were made to assess their specific beliefs about science as a connected and coherent discipline?*" addresses the testing effect on the study subjects. This participation might have increased the probability of the transfer of their beliefs into their classroom practice. Two types of testing effects may have influenced this study: 1) the effect on the three teachers that completed the SMS task at the beginning of the study, and 2) sensitizing the teachers to thinking differently about science and developing a revised SMS by simply participating in the study.

The first testing effect concerns whether asking the three teachers about their subject matter structure prior to the classroom observations was an assessment of their beliefs or it acted as a treatment causing the teachers to think about the SMS. To address this testing concern, the three teachers were asked if they had thought about science this way on the first and second administration of the SMS task. The responses were compared for these three teachers and among all the teachers. Another check occurred between the two SMS tasks for the three teachers; differences or similarities were noted. High congruence indicated little effect. Limited congruence indicated the potential for effect or other factors, which influenced the teachers' beliefs.

To address the second testing effect, a comparison was made of the teachers' survey responses before and after the classroom observations. For a second time they were asked two of the survey questions. These questions asked whether they had ever thought about science as connected and coherent. By asking before and after the observations it was hoped that any inconsistencies could be found. Using the two approaches - two attempts at drawing the SMS and responding to the survey questions twice – helped the researcher to determine if the teachers were sensitized by being asked questions about their beliefs about the connectedness and coherence of science during the period of the study.

Each was also asked directly about how she/he was influenced by participating in this study. In the second interview they were asked about the whether they had ever thought about science in a connected or coherent fashion. A high congruence in the stated survey responses and exhibited practice of the teachers who took the SMS task twice was considered as a lack of evidence of the testing effect. If there was a low congruence of

stated SMS, the survey responses, and the exhibited practice, then this was considered as possible evidence of testing effect. The answer to this question about the testing effect has implications for the interpretation of the results concerning the translation of beliefs about science into classroom practice. The implications for this study will be further explained in Chapter VI.

Chapter IV: The Teachers - Data Analysis

Introduction

An individual analysis of the information and materials collected for each teacher is presented in this chapter. The sources for each analysis include a survey, two interviews, classroom observations, researcher notes, and instructional materials. The data is compiled to present a general profile of each of the six teachers. Direct quotations from the teachers have been edited for clarity and to illustrate the beliefs and ideas of the teachers. Each teacher profile is divided into five sections: *Academic and Professional Profile*, *Class-Specific Perceptions and Concerns*, *Classroom Practice*, *Self-Described Subject Matter Structure*, and *Summary*. There is also an introduction for each teacher describing his or her teaching situation, experience, community and school. The primary sources of data used are discussed for each teacher.

The first section provides an *Academic and Professional Profile*. The information in this section was gathered primarily from the initial interview, and illustrates each teacher's academic history and professional activity. Background about the community, school and teaching situation are described for each teacher and found in Appendix H.

The second section, *Class-Specific Perceptions and Concerns*, describes the teachers' concerns about teaching science, what science is, how they make choices about what science to teach, how they stay current in science, their curriculum choices, and their perceptions about teaching in their school. This section provides a general picture of the teacher's philosophy, concerns, and challenges in teaching science at the middle school. Inconsistencies in their perceptions and beliefs are noted when they occur.

The third section, *Classroom Practice*, uses the observation data, instructional materials, student materials and researcher's notes to provide a picture of the actual practice by the teachers as it relates to their subject matter beliefs about science. An analysis of this data describes how they incorporate their beliefs about science into their teaching. This section presents the actual practice as observed.

The fourth section, the *Self-Described Subject Matter Structure*, reports what the teachers have said in the two interviews and have drawn in their SMS concept map

diagrams about how they think about the science they teach. This section further refines a picture of their individual beliefs about science and outside influences on their teaching of science.

The fifth section, a *Summary*, responds to the original question in this study for each of the individual teachers. A comparison between the researcher's and the teachers' perceptions about their beliefs about science is provided. Conclusions regarding relationships between the teachers' beliefs about science and their practice is discussed, as well as when appropriate any intervening factors which may enhance or prevent a direct transfer of ideas.

Final conclusions based on all the teachers and their beliefs and practices are in Chapter VI, as are implications and recommendations for science teacher education.

Daniel: South Middle School

Introduction

Daniel is a 6th grade science teacher at the South Middle School. Daniel has taught science for more than ten years.

Academic and Professional Profile

After graduating from high school and before attending college, Daniel worked for several years in a paper mill. He stated that this job struck him as a dead end so he applied to and attended the local state university in horticulture, receiving a two-year degree. He worked for a few years in his own lawn and landscaping company using his knowledge of horticulture. During this time he began to volunteer in a local elementary school doing presentations in science. Through these classroom visits he became interested in teaching, and went back to college, finishing his degree in science and in teaching.

He currently reads journals and attends an occasional conference to learn more about science teaching. He is also working on his Master of Science degree at a local

private university. His graduate program has a focus on creativity and he has been developing lessons that encourage students' creative thinking.

When asked about the influence of his past science courses on his teaching of science, he talked about both his work with science and about the science courses.

Besides studying science, I used to work in the USDA in agricultural research as a technical assistant. I have a pretty good idea of how science really plays out in the real world.

He believes his experience in science affects his thinking in terms of how science applies in the world. He tries to connect the science he teaches to the real world.

Class-Specific Perception and Concerns

Daniel's concerns are related to instructional materials, the alignment of curriculum with state standards, and instructional methods to keep the interest of his students. He doesn't talk much about his students' abilities or the community. Daniel's science class is a comfortable place. Students are responsive to his requests and seem happy to be there. He usually divides his classroom instructional time into two different types of activities. Students, for example, might work on a hands-on activity and then switch to taking notes.

For instructional materials, he uses a variety of books, kits, and resources. He does not use a textbook, even though the school has one for the sixth grade.

I would say 95-97% probably is outside the book.

Daniel likes independent projects and investigations, as an alternative to using a textbook. He creates and uses open-ended activities to promote multiple ways of success in an activity, especially when special education, average and gifted and talented students are all in one classroom. He emphasizes problem solving as an important skill.

As long as the information is accurate, I feel like if we are doing a challenge or activity that incorporates the same ideas in different ways that make more connections for kids, it's okay.

He does not completely reject published materials. He was observed using some materials from a new middle school science kit program that the school was piloting. He said he liked some aspects of the kit and not others. One problem was that he did not

have a computer that could run the CD ROM, which was a pictorial glossary and guide for students to use with the activities in the kit. He liked the hands-on materials in the kits and how they were organized. The unit with the kit was divided into two blocks of time because of snow days, so the observation of these materials was disjointed.

He would like to do more guided discovery type of activities, but his classroom has very little lab equipment and he has a small budget for purchasing new equipment.

> *Very little of this set up [his classroom] is conducive to labs. We do not have sinks, and really no lab equipment. Can't use the lab or the lab Bunsen burners. So a lot of the things we do are more activities rather than labs. I would like to do more of those. I have a four hundred dollar budget for one hundred and twelve kids.*

A strength of Daniel's was observed in two different contexts: in designing and using of open-ended activities, and in guiding his students through them. One example of this is scheduled into his curriculum. His students complete a self-selected independent project each quarter. These projects have a set of requirements and grading criteria, but the selection of the topic is of the student's own choice. Daniel does intervene and help students narrow their topics. Students cannot select the same topic (such as animals) every time quarter, but have to select topics for different areas of science.

> *I do a quarterly project. It is self-selection. There are criteria. They have to have a report with a bibliography, they have to make a visual to show with it, and they have to present it to the class. So if you have an interest in space or plants or things that we are not going to take up this year, this is an opportunity to learn about something you are interested in.*

Daniel believes that peer pressure is a strong influence on his students, but he encourages them to take risks with ideas and conclusions anyway.

> *Peer pressure rules their [students] whole lives here. You try to be a good role model and you try to set the stage for risk taking and stretch a little bit and reach beyond your limits or something like that. If kids are not comfortable and they are going to get teased or called names that negates anything you do here.*

The awareness of his students' developmental level and social posture influences Daniel's instructional approaches. He is aware of their general attitudes and develops and gauges his instruction accordingly.

Classroom Practice

The information used to determine the classroom practice description included the recorded observations, lesson materials and researcher notes. One unit was observed completely. An integrated unit that connected to the whole sixth-grade team was observed completely. Daniel had students design and test a catapult for throwing accuracy and distance. Two other units were observed, but not completely. The first was the beginning of the student independent research project. In this unit, students were researching in the library for their independent projects. The other unit came at the end of one on earth science.

The recorded content "coverage" is portrayed in table 6. It shows that Daniel incorporates a variety of curriculum topics during these particular units. The topical flexibility Daniel has developed into his curriculum with the student independent projects and investigations as in the medieval unit, show up in the table as the Nature of Science, Common Themes and Habits of Mind, and in the non-stated curricular Benchmarks.

He has a strong emphasis on problem solving and inquiry (Nature of Science, Common Themes and Habits of Mind). This represented a fairy high number of records in the table as compared to the stated curriculum Benchmarks. This pattern could be interpreted, as the topics selected were important to the teacher; yet, the taught topics were not connected to each other or to the other stated content topics. For example, in the unit on forces using the catapult, little observed time included questions or discussion about gravity, forces, or quantitative methods for collecting information about those forces such as velocity, and speed. Instead the catapult activity was primarily an inquiry activity with little other content represented.

Daniel develops much of his curriculum himself and students play a role in selecting one aspect of the content through the independent project. Hence, it was sometimes difficult to determine precisely the stated or non-stated curriculum. In many observations, the Nature of Science and Habits of Mind were recorded as the core topic

areas for a lesson. The classroom materials were not clear enough about the teacher's intention to determine whether there was more to the unit. The science of forces in a catapult could have provided the context for inquiry. Little mention of physics occurred in the classroom; thus the content of the unit was categorized in the Nature of Science, Common Themes and Habits of Mind categories.

Table 6: Daniel - Science Content

	Number of records	Records in areas within those Benchmarks
Nature of science, common themes, and habits of mind	52	3 of 13
Other stated content curricular Benchmarks	85	7 of 7
Non-stated curricular Benchmarks	34	9 of 24

Even with the variety of science foci in Daniel's classroom, there appeared to be an emphasis on the Nature of Science, Common Themes and Habits of Mind and other stated content curriculum. The inclusion of many open-ended activities is recorded as an emphasis to the Nature of Science, Common Themes and Habits of Mind category. Because the observations in Daniel's classroom involved two units as well as the start of the student independent project, the variety of science topics recorded was high. However, the focus within each unit was strong enough to show that he did focus on the core ideas of the intended unit and didn't just cover topics randomly.

The greatest numbers of connections made were to inquiry, problem solving and broad array of topics generated by the students for their independent projects. The connections made in the classroom were compared to the Project 2061 Atlas of Science Literacy (AAAS, 2001) as a representative articulation of the connections within science. In the category of the Nature of Science, students were explicitly encouraged to notice and criticize the reasoning and statistics in each other's arguments.

The building and testing of the catapults as taught was categorized as the Nature of Science and Habits of Mind rather than Forces, at the grade 6-8 level. According to the Atlas, there could have been connections to areas such as the solar system or the role of gravity, but none were made. During the observed unit on earth science, there were no

connections made to states of matter, natural selection or biological evolution as examples of the types of other content links.

The topics in the students' independent projects broadened the recorded science taught in Daniel's classroom. These topics helped make science more relevant for many students, as the topics were student-selected. There was no observed attempt by the teacher, however, to link those topics to other science topics in the teacher-selected instructional units. There were connections in the open-ended investigations and independent projects. Because there were connections in some areas and a lack of explicit connections in the earth science and catapult units, it is difficult to render a definitive determination of Daniel's intentions for connections within science.

It appears that Daniel would like to have made connections in the other instructional units, but he does not make them in the more traditional teacher-led instructional units. Some of this difficulty in determining his intention may have been due to the low number of visits for Daniel during the earth science unit. This unit may have been more typical of what he taught, but his interviews helped clarify his more typical instructional approaches. The classroom observations in Daniel's class were interrupted by three snow days and three days of teacher absences; therefore some of the coherency was hard to discern.

Self-Described Subject Matter Structure

This section describes Daniel's stated beliefs about his Subject Matter Structure and specifically his beliefs about the coherence and connections within science. Both interviews, two repeated survey questions and the Structure Matter Structure task are included as data sources for this section.

Daniel describes his belief about the nature of science while framing it in the context of his year and his students. He focuses on the ability of his students to reason and think about ideas as a big part of what he teaches in science.

> *Kids have all kinds of notions of what science is, and how science is like boiling things in test tubes and science is this and science is that. I try to impress on them that it is a way of looking at things, different ways of looking at what you see and different ways to understand something you are seeing. There really is not just*

one answer to anything. Everything has lots of different angles, perspectives and answers.

A review of how he responded on the survey provides some further clarity about how Daniel thinks about science. For the two survey questions, Daniel's responses were consistent for the way in which he says students better understand science and for how the changing nature of science affects student learning.

In the original survey, he checked the following response: *It is best for students to learn science ideas in an integrated way such as with themes as students would be encouraged to make connections to other subjects areas and that science ideas are parts of a theme.* However, in the second interview, he chose a different response: *that it is best for students to learn science through connecting science concepts*. The second time the question was asked the choices were limited to force a selection either a connected or unconnected response. He selected the connected response both times. He described his choice thus:

If you take things out of context, it has no application. As soon as we start doing means and modes on the board,[they say] wait a minute this is math, this isn't science. They just can't believe that they did two hours of math today in science. The more they see that things are connected like doing interdisciplinary things, like the medieval unit, is more relevant like doing one project in one class. They will probably see more value in it.

For the second question in the survey he selected the following answer*: Learn the discipline of science such as biology, chemistry and physics over period of years to be able to learn about new discoveries,* to indicate how students should learn science today. And, for the second response to this question, he stated that students should be exposed to a variety of science learning in multiple areas of science. From these two examples of Daniel's beliefs at the beginning and end of the study, did not change during the period of the study.

In one of his explanations for his beliefs about science, he characterizes science as an ever-changing discipline.

Science is such a changing area. It just changes so fast. I think really now science teachers can't really know all the facts. They are good at finding the information.

I think that it is really the strength of science. Nobody can keep up with this volume of information.

He believes that to teach science to students, science teachers should teach the most important points, and some processes and vocabulary so that students can get a handle on the topic. Teachers can then work with students on how to get more information and how to use it, how to look at and solve problems. The teacher does not own the information but has to help students access it in order to learn it.

[There are] probably very few truths in science. What we grab onto today as the greatest way, down the line it could be... solved... but the bigger piece is here. Look at dinosaur research. In the last two years there have been some incredible things that have been found and theories have been shattered

One concern he has about learning science at his grade level is how students think. He says they are quick to make judgments about ideas, and they will base arguments on only one fact. He says students have a hard time making decisions if they are faced with a lot of information and if some of it is contradictory. They are not used to making hard choices based on lots of information. He believes that his students like to be given the right answer to questions, and in science there are few right answers. He feels that it is a hard thing for them to understand, and sometimes they are confused by conflicting ideas.

You can only interpret the data you have, and if you only have this small amount of information, you have to make our assumptions on that. It is a hard thing to come about, to drive home to kids. Sometimes they are confused by it and I think other kids like the fact that there is more than one answer to a problem. More than one approach to a problem.

He portrays Maine's state science standards as being much more focused on science than on science education. Science to Daniel is broader than what he finds in the state's standards. The standards force him to teach specific topics. He says because of the standards, he now teaches a little less of the peripheral things and focuses more on the topics in the standards. He is not sure if he likes this or not.

The way that we do it here at school, and the way the Learning Results have it, everyone has to break up the pie. You take a piece and you take a piece. Ideally, I

would like to do some physical science and I would like to do a little chemistry and a little of this and do little of everything. But the way the curriculum is set up and the Learning Results are set up you almost have to specialize; you know I will take this, this and this. So when they come out of here, everybody will get everything, but you won't get overlaps and gaps.

Even with his focus on filling gaps in science and focusing on building a more coherent curriculum, he believes that it's important that his students understand the processes of science. For example, his thinking about the importance of being able to reason and think scientifically is explained in a statement about the catapult activity.

The problem solving is the filet mignon of the whole thing. Also the creativity part. One of the things that I got back from the [student] reflection was that the kids were very upset they didn't have a whole lot of things to choose from. Three feet of tape, two nails and one block; they had a small list of things to work with. And they thought it would be a whole lot better if they could bring in things and have as much tape as they wanted. Fourteen extra rubber bands and ... They wanted a lot of things to choose from. Mostly with the problem solving, it was change and design and variables.

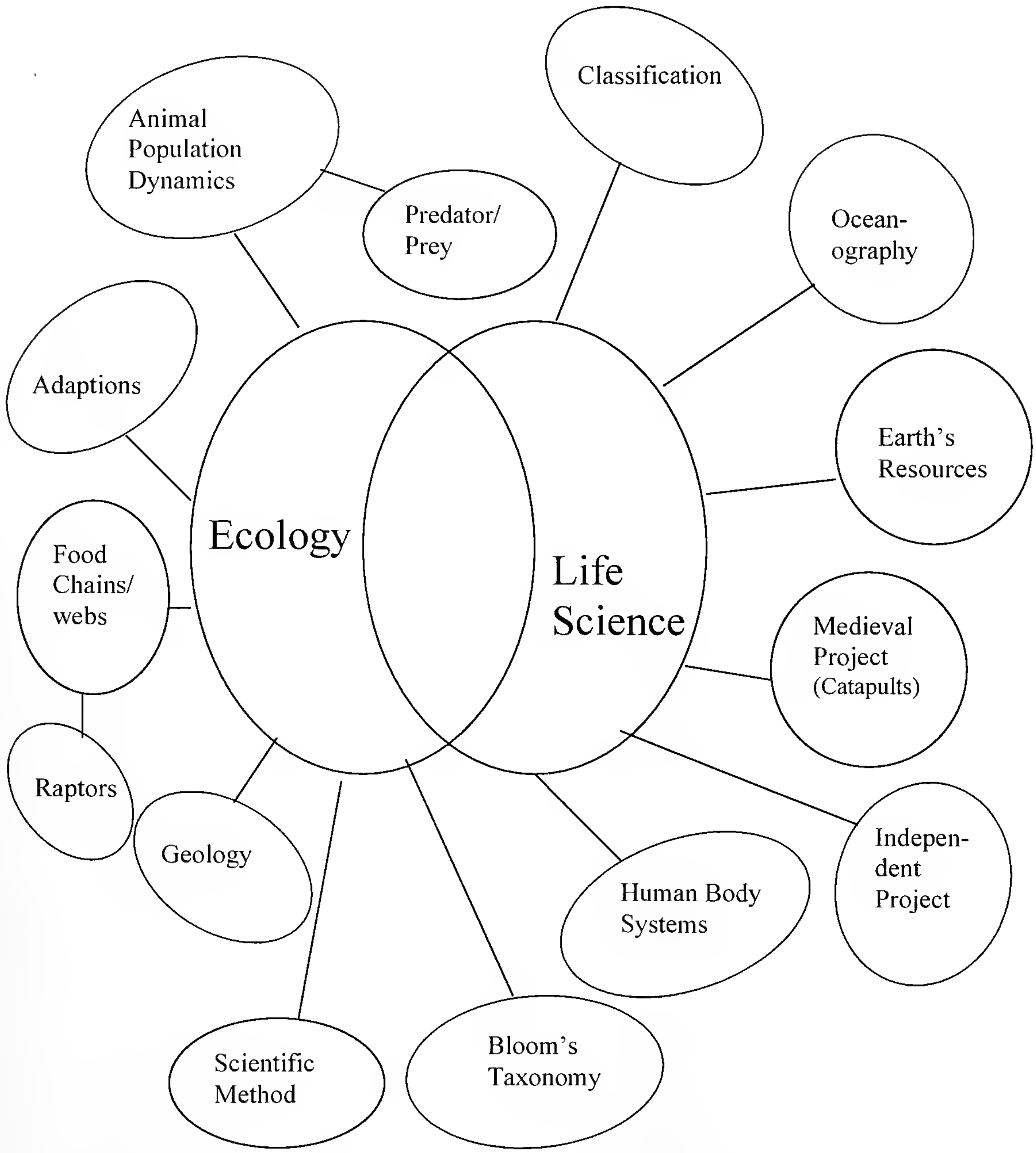
The Subject Matter Structure (SMS) diagram he drew illustrates his thinking about the content he teaches. By the size of the circles he drew, it is evident that he emphasizes ecology and life science as the core content, with other aspects of science branching off from those two topics. The scientific method is represented in the diagram as equal to most of the other topics. The scientific method is not visually woven into the content topics, although in his interviews he talked about it as being almost the most important aspect of science.

He describes his diagram as focusing on the same core ideas.

The centerpiece of the curriculum that I teach would fall under ecology or life sciences and that is why the two circles are like or not quite a Venn but that is the best I could put it.

The diagram shows that he has connections to the core ideas, but there are no connections from one topic to another. This confirms what was observed when he made transitions between his units.

Figure 3: Daniel: SMS Diagram – After Classroom Observations



When asked about his emphasis on the processes of science in his classroom, and their not showing up strongly in the diagram, he explained it in the context of another open-ended activity he does with his students.

Like we do Bloom's Taxonomy and problem solving and how people learn to be better learners. The medieval project is an extension of problem solving. You know, here is the problem... find a way to design, and we then want that one thing. I wish you could have been here when we did the great straw caper. I gave them pins and straws and told them to get into groups of threes. The tallest free-standing structures using pins and straws, and how they went about it and the collaboration end of it. It was just amazing to see how kids did this. They built structures that touched the ceiling. Just with straws and straight pins.

From the two conflicting sources, it is difficult to determine if he sees the scientific method as integrated into all that he does or as a separate content topic that he teaches as a unit. He showed it as integrated in the student independent project, but separate with the medieval catapult construction. It may be that his thinking about the connections within science is not stable or clear.

Finally, he believes that his background in science does affect his teaching of science. His past experience working in science is his reason for doing open-ended activities. He believes his experience gives him an unique perspective on the world.

They [people with a science background] are going to look at the empirical data. Let's look at the facts. Other people may look at how it feels inside, maybe ignore facts or not look for any facts at all. It is a philosophical difference about what you base your judgments on whether it is empirical or emotional.

Daniel's SMS is broad as seen in his diagram, and focused on the processes of science as heard in his interviews. It is this combination that seems to characterize his thinking about science and his teaching of science.

Summary for Daniel

The SMS that Daniel held at the end of this investigation has two focal points. One is the content of science as seen in his SMS diagram and the other is the process of science as heard through his interviews and observations. These areas, the content and process of science, seem at times to be integrated and other times not. The content consists primarily of life sciences with a few other secondary topics such as the medieval unit and the newly piloted earth sciences materials. The process of science for him is

scientific inquiry, research methods, critical thinking and reasoning, experimentation, and communication.

To answer the question, "*Is science, as a discipline, a connected and coherent field of study, or is it comprised of separate areas of study,*" for Daniel, one has only to look at the matrix of his classroom practice and to listen to him talk about science as a discipline. He demonstrated that he does believe that science is a connected discipline; yet the classroom observations recorded a variety of topics taught.

He talks about science being related and ever changing. He allows for broad content learning by his students in their independent projects and he spends instructional time on the processes of science and on helping his students develop independent thinking. The connections in science seem implicit rather than explicit for students since he does not explicitly illustrate the connections in science. The connections are made through the different curriculum instructional units and not within classroom time. The demonstration of connections in science for Daniel is at the curriculum level and not the instructional level.

Daniel's beliefs about science and his background have led him to develop much of his curriculum. His knowledge and experience have affected what instructional materials he uses and how he uses them. The rejection of the textbook demonstrates his strong beliefs about what he thinks should be taught. It is also possible that his knowledge of this area of science is weak so that he focuses on the processes of science.

The classroom and curriculum situation for Daniel show that he is currently in conflict about his own ideas about science and teaching science and standards, whether state, district or curricular. It appears that he still mostly uses his own materials and is deciding on their value and how to integrate state standards into his teaching. The direct influence of standards as shown in the TIMSS tripartite model of curriculum does not apply, as his beliefs about science are stronger than his intention to follow a curriculum and they have not changed because of state, district, textbook curricular influences. Or Daniel's thinking might be interpreted as curricular influence just now being considered and it is beginning to affect his beliefs about science. This may be the better interpretation. Since he described the standards as causing him to rethink his teaching, he is now teaching fewer topics than he used to teach.

At the point of this investigation, Daniel's ideas about science and science teaching are consistent, in that he sees science as a process of learning about the world, which is ever changing. His beliefs about the coherence and connections of science do not seem to impede his instruction. He believes that his sixth graders need to think and reason well; his instruction in science reflects this. His belief about the connections and coherence of other science content is not clear because coherence in science content is not something he talks about. He did describe how he emphasizes the growth of his students' thinking over the year. It appears that his focus on coherence is in terms of the development of his students' Habits of Mind rather than focus on content coherence.

Overall, there is a relationship between his beliefs and knowledge regarding the coherence and connectedness of science concepts and their classroom practice. The relationship is strongest in the areas of the connectedness of science within the processes of science. He demonstrates many connections in science through his discussions about his beliefs, illustrations describing the science he teaches, and in his classroom practice of doing independent projects and open-ended activities. He neither demonstrated nor articulated the coherence of science in a complete way; his beliefs strongly favor scientific thinking. That bias is seen in his classroom and when he talks about science and teaching science. Given this analysis, Daniel is primarily a Type III teacher: unfocused on the stated content and focused on the nature of science relative to the other content areas.

Patricia: Coastal Middle School

Introduction

Patricia teaches seventh grade at the Coastal Middle School located in a growing middle class suburban community in southern Maine.

Academic and Professional Profile

Patricia was a pre-med major in college and graduated with a degree in medical technology. Her first career was as a medical technologist where she worked in a laboratory analyzing blood samples. She stopped working when she had her children.

When she decided to return to work, she noticed that her previous job in the medical field had substantially changed. Many of the things she used to do were being automated, HIV inflection was a high concern, and rotating shifts and working during the weekends did not interest her. When her children started school, she began to volunteer in school and at the town's library. She found that she loved to work with children and decided that teaching would be something she might enjoy.

To obtain her teaching certificate she attended a fifth year teacher education program at a local state university. She said that she is well prepared to teach her middle school students.

> *Yeah, I feel that I am prepared to teach this level of science. I student- taught in a high school chemistry class and in a first grade class. Even though I know the general concepts in chemistry, I would have to take some chemistry classes to get the nitty gritty to be able to answer all of their [high school student] questions.*

She subscribes to science journals, is a member of the National Science Teachers' Association and goes to some science conferences. Mostly she finds that reading is the best way to learn new things in science.

Class-Specific Perceptions and Concerns

Patricia's primary concern is with how to integrate the state and national standards into what and how she teaches as she is unsure how the national and state standards should impact her curriculum and practice. The curricular topics are varied in the state's *Learning Results*. She prefers spending time on topics and going into depth about them rather than covering them superficially.

> *I am not a filler person. You know, standards make me uncomfortable, in science, because, the spectrum is too great. Saying one part of science is more important than another part is difficult for me. The Learning Results for the state right now, [are expansive, so even] if I went year round, I couldn't teach so that my kids would come away with that as essential knowledge.*

Even though she worries about how she is teaching science as related to state standards, some of what she says implies that she already knows how to and already

incorporates them. She may not call the ideas standards, but her statements reflect what the standards are recommending teachers do who teach science.

I think that one of the big pushes is the connection that is around. When we do cells, on to respiration and that type of thing. And then when we do plants how photosynthesis, the simple formula is reversed, and how it is connected. Also connection of how so many things are different. Mother Nature has one rule, and she just modified it. Everything has a little adaptation and change.

She articulates the importance of connections in science and recognizes them as part of the current reform effort in science education. The integration of these ideas into her practice is where she is not sure if she is doing it well.

Having students frequently work in groups is uncomfortable for her because of student chatting, but she realizes that socializing for middle school students is important and helps students work out ideas. She has lab tables where students work together as lab partners and periodically regroups them randomly. Sometimes the students will move nine or ten times during the year.

Having deadlines for the completion of a unit or project helps her move on to new topics. She understands that on some days her students will be much more focused and able to grasp complex ideas than on other days. She also realizes that her students have preconceived ideas that hinder their learning. She struggles with what methods and curriculum to help them through these ideas, as the students seem resistant to changes in their ideas. She sometimes feels a little guilty that she doesn't provide a larger variety of methods to use for student interaction and learning.

Her curriculum development process and use does not involve the use of a single resource.

I developed my own curriculum. I do not use a book. When I decide to teach something I read zillions of different books. I look at textbooks, and glean whatever I can find on a subject, figure out what information I want my kids to know, and then figure out how I am going to expose them to it.

She first looks at the broad concept in the content and then focuses on the topics. She then has her students study those topics from different perspectives. She explains this process with the example of respiration. This development of an idea builds coherence

and connection to the various sciences in her class. This process also seems to help her see the larger picture, allowing her to make connections to other areas of science when appropriate.

> *[When] I teach respiration and I start it in cells because that is the energy, that is the reason. When I go to lungs it takes me six weeks in making connections before they have a clue of what I am talking about. They can recite it and tell me about it and we see it a lot of times. We use it, but until it is cemented, it takes about a good six weeks of seeing it different ways.*

When asked about how she determines the sequence of science ideas or concepts she is able to describe her thinking process to develop a science concept. She does think about the sequence of activities in a unit to promote the best learning for her students.

> *I start with the big idea. I learn everything about it. And then I decide what I can teach, how much time I have, what I can teach my kids, and finally what do I feel is most important for them to understand in order for them to come away and understand a good amount of this, enough to remember?*

She tries to prepare activities to illustrate science through real examples. For an observed evolution unit, she used photographs of various animals for students to see differences and similarities in animals over long periods of time. When asked about what she meant by illustrating through real examples, she described a series of activities in respiration.

> *When I do respiration, the reason you breath out is the muscles relax and push you back in. I mean the way you breath out is because of muscle recoil, but it is mostly because of surfactant on your stretched liquids, and as soon as the pressure is released it gets pushed out. We do those kinds of things. We do pennies and watch water bumps and describe how water recoils. What holds your lungs up is a fluid barrier, a suction. Also we suction things such as Mylar with plastic and duck tape to the board and kids try to pull them off.*

Her perception of what her colleagues think about her as a teacher is that she is a hard teacher. Patricia said that what is hard about her class is the vocabulary, especially for students with learning disabilities. She uses different instructional techniques and materials to help students learn ideas in science, and she works with individual students

who are having difficulty with her class. She is available for help every day after school, except Wednesday when she has team leader meeting. She allows kids to make up tests, and she provides modified tests for special education students.

Classroom Observations

This section describes data from classroom observations for Patricia, instructional materials, teacher and student handouts, and researcher notes from the observations.

There were two units observed in Patricia's class, neither one from beginning to end. The first set of observations occurred at a later part of a unit about evolution. The second set of observations was the beginning of an integrated unit on Egypt as a part of her middle school team curriculum.

Table 7 shows the recorded science topics during the two units. The recorded topics indicate that Patricia tends to stay within the intended curricular discipline focus. Her discipline emphasis is focused on the science content in the unit. At the same time, she makes curricular connections to topics that might not traditionally seem to fit in the curriculum or is what might be thought of as a different science topic area. An example of this is in her evolution unit. She was describing fossils and how old they are and how the age leads scientists to be able to place animals along a time scale. This allows them to be able to see physical changes in those animals over time. She continued with how scientists determine how old a fossil is through atomic decay. There were two days of class time related to atomic decay. The researcher observed several classes where students figured out how old fossils were by their chemical composition.

This link to chemistry is not typical when teaching evolution. She describes these connections as links to other aspects of her intended curriculum that she will come back to or has already covered, and sometimes even to topics she does not intend to teach. This deliberate linking of science to other areas indicates a purposeful coherence to the science she is teaching.

Table 7: Patricia - Science Content

	Number of records	Records in areas within those Benchmarks
Nature of science, common themes, and habits of mind	16	5 of 13
Other stated content curricular Benchmarks	119	3 of 6
Non-stated curricular Benchmarks	71	12 of 24

There were low numbers of topics recorded in the Nature of Science, Common Themes and Habits of Mind categories. This could indicate a more didactic approach to teaching or something more complex, such as how the unit observed may have lent itself to this type of teaching. Patricia did indicate in her interview that she felt this unit had more hands-on activities than others.

The number of connections made in her curriculum to other science areas is relatively high compared to connections made by other teachers in the study, even while she stays focused on the discipline topic in the unit she is teaching. She talks more about making connections within her instruction and about returning to ideas so that students will better understand the concept.

> *I tend to bring it back. When we start anatomy, I bring it back and show them two or three different ways of what it looks like. They will have pictures and we will draw it ... I will also have several demonstrations, more than one of how things work.*

The connections that Patricia made to other science discipline topics are quite similar to the Project 2061 Atlas for Science Literacy (AAAS, 2001) grade 6-8 level connections. In her unit on evolution, she made connections to inherited characteristics, variation in inherited characteristics, and cell function. These ideas were described in the Atlas as appropriate connections to other disciplines. She also made connections to chemistry through the idea of carbon dating. She did not talk much about changes in the earth's surface, a connection to the concept of evolution in the Atlas.

Another way to examine the nature of the connections in science is to look at the subtopics presented in the unit. The number of connections to science ideas within the broader science topics outside of the curriculum unit were many and varied. This means that she made connections to other science areas. They represented a wide array of topics,

12 out of 24 possible ones. This is about one third of the possible connections within the areas she covered. For example, she was studying evolution. She might have made one or two connections to other areas of life science, but she linked evolution to a much broader range of other life science topics.

Patricia appeared to be intentional about the connections she made in the classroom. She was even deliberate when new topics came up in class. She either answered the question or topic right away if it connected to the topic she was covering as desired, or she would defer thc question to another unit, or say she would not teach it this year. This behavior represents a deliberate selection of the topic taught or discussed in her class, particularly because her curriculum is not based on a textbook. She makes purposeful decisions about the science content and in what order it is presented.

Self-Described Subject Matter Structure

Patricia's subject matter structure here is determined by what she said in the interviews, by illustrations in her concept map diagram, and by how consistent her beliefs are as determined by the survey. The combination of these factors lead to a picture of what she thinks about science and teaching science.

Patricia has clear ideas about the content she teaches, and what students should learn. These ideas come from her science background and her beliefs about the core areas in science for her students. As a premed student, Patricia took many science courses, especially chemistry. She says chemistry is important and is found in all sciences.

> *Chemistry is my minor. To me everything is chemistry. Everything that is life science is chemistry, so that is why I start with chemistry. I will pull it in again and again for kids. We will see some of it. Partly because I love it.*

Even though she has high standards for her students and expects them to know the vocabulary as well as the concepts of science, she also states that factual knowledge is not what she really wants her students to learn from science. She does not articulate her goal for student learning in science, but she is able to say what her goal is not.

> *I am not really sure what I want them to know... My goal is not for them to know facts. What I am looking for is for them to question and figure out, because evolution is something that is far from exact. To find relationships between things*

and to be able to think past what things could be. There were a few times I brought in this skeleton. And I will bring that back. When we do skeletons, I will have dinosaur skeletons, bird skeletons and that kind of stuff so that we can compare and I will bring evolution back. To see if we are related and where does it come from.

Her goal for science learning appears closely related to the process of thinking scientifically, evaluating relationships and connections of ideas, and asking questions and making decisions. On one hand, she describes the importance of learning about science, and she also talks about thinking scientifically. These two views are not incompatible if both are considered science content.

When asked if she could cut or change what she currently teaches in science, she talks about wanting to be more focused in some areas. This might imply that she wants to focus on more content. Because of her mixed beliefs about her goals, she would not only increase the content of the specific topic, but would also have her students use the skills of science to the same extent in that area.

Believe it or not, I am really an advocate of depth vs. breadth so I would cut out about half of the topics in both classes so we can do more quality as opposed to quantity.

From her classroom observations, it appears she could spend a great deal of time on one subject and not be bored. She would also offer a variety of activities so that students could experience the topics in several different ways.

Based on her survey response, her ideas remained consistent over the study. Her response to the first survey question on how students should learn science on the original survey was that, *"It is best for students to learn science through connecting science concepts in different contexts such as energy flow in ecosystems and photosynthesis as they build knowledge about common aspects of the discipline of science."* Later when asked in the second interview about her choice for this question, she selected connections within science. She explained her choice.

If I could do whatever I wanted as far as planning, I think the sciences should not be separated. However you have to teach pockets. If sciences were not separated, it would be a perfect world. They have already learned the science, like the

human body when you do the physics of movement, and the chemistry because every human is all chemistry and then the biology that goes on with it. Everything is connected. When I do bones, I want to do physics too. Even do robotics. Now that we have made these bones, how do we move them? Then the nerves come in. And then what are you going to put in the joints?

Without prompting, she articulated the connectedness of science. The connections in science are a way to see the world and seem to be important to her.

In her classroom, she uses demonstrations, and conducts labs and activities with students. These instructional approaches give students different opportunities to learn science. She said she probably teaches the way that is most comfortable for her. She thinks the methods she chooses would make it easy for her to learn science, so she uses them with her students. Even with using multiple instructional methods, she still wonders about how well she is reaching her students. This represents an open mind about the best way to teach and that she may not yet have found the "right" way.

Well, I think it is wonderful for them to understand that they can explore the world and feel empowered by that by learning how to ask questions, problem solve the design of an experiment and that it is okay to be wrong in science. Sometimes it is great to be wrong in science because it is just learning. That gives them a lot of freedom to explore.

She tries to teach kids a questioning attitude and how science ideas are developed and maintained over time. She also tries to make connections in science such as how many things in nature are different, but are also similar in many ways. She works to teach them what science is and can and cannot do.

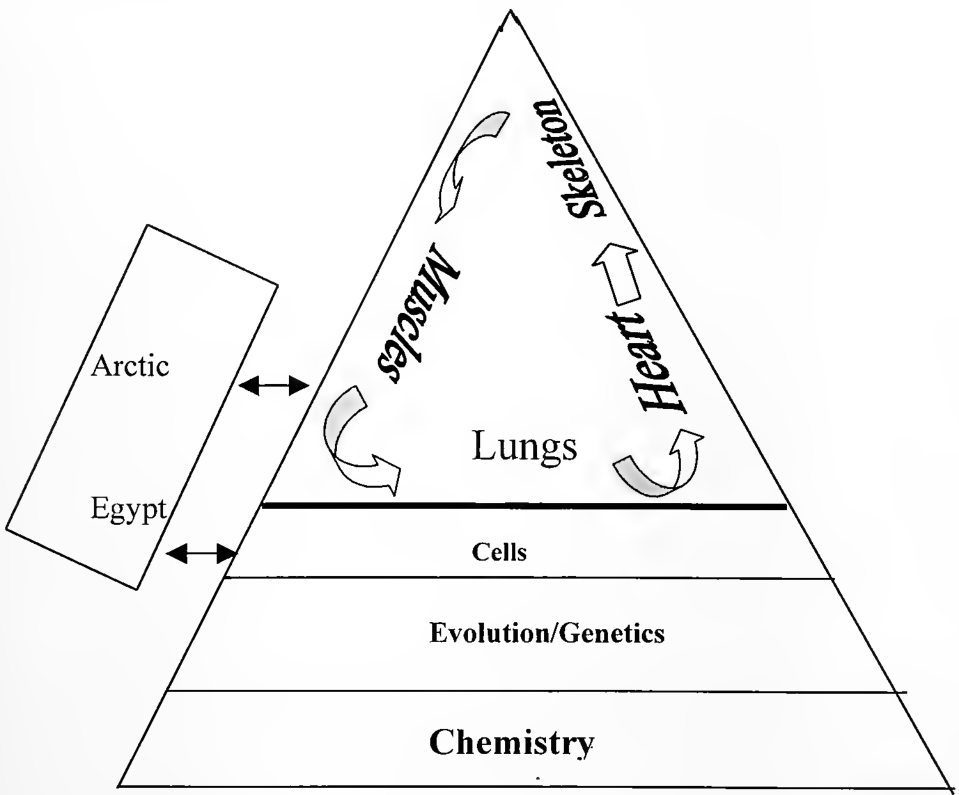
I need the kids to understand that we are talking about theories and theories are not a hypothesis. I also want them to know how long, when we came, on the time chart here. There we were and I need them to understand how long viruses have been around... And then things came out of the water and on to land. We put some things in water, we did a time line. Part of it was to teach timelines to support them being done. We did a lab on fossils. One of the their [homework] questions was how man evolved. What I was looking for was for them to understand adaptations. Why they would say what they were good for. Then we moved on to

actual fossils - who digs them up, how do you know how old they are, carbon dating that kind of thing. I don't move past carbon dating.

The completion of the SMS task illustrates how she thinks about the content she teaches. She drew the diagram of her curriculum fairly quickly and was able to explain the aspects of the diagram.

I start with Chemistry. Then we move to evolution and genetics, because I want kids to understand adaptations and how things change and why. Then we move to cells because cells are the building blocks and this is where genetics happens. And then when I move to the human body this is all completely, you can't separate it, they are completely connected. That is the top.

Figure 4: Patricia: SMS Diagram – After Classroom Observations



In this diagram she put the science topics in a hierarchical order from chemistry at the bottom to the concepts on top. The concepts of evolution/genetics and cells are those that lead to an understanding of the human system. She shows in her diagram how human

systems concepts are connected with the arrows. There is a coherency to the science curriculum when drawn in this fashion; you can see the way the concepts interact.

Another interesting part of this diagram is the two topics that are a part of her middle school team interdisciplinary units. She includes them in her drawing but they are off to the side. She illustrates that they don't connect well with her science curriculum. She describes how she placed them.

> *Because this is what I have really thought about how I teach and why it is this way. I didn't know where to put these [Arctic and Egypt] to be in there. I mean it doesn't fit neatly in my little triangle, but the arrows show you that it certainly relates.*

She agrees with the middle school concept of having integrated units, but expressed some frustration about the time the integrated units take from her science teaching.

When Patricia describes people who have a science background they tend to be people who think differently about the world and how the world works. They tend to be more analytical, and want to see the whole picture of a situation or problem. They want support for ideas to come from research or examples. She thinks science people question ideas and things much more than other people. Finally she thinks that they see how science ideas are connected.

> *I think people who are into science tend to think differently about things. Is that what you mean? That they tend to be more analytical, tend to want to see the whole picture. They tend to want to know if you say this, then how can you see it. Where is the research or where is the... But if you get into a science field where you have to work at science no matter what it is, then you understand the connections..*

Her beliefs about the connections within science are strong. The word connection is mentioned over and over in her conversation about science and teaching science. She sees many connections in science and tries to help her students understand those connections. She thinks adults are the ones that separate the sciences into areas, not students.

I don't think students understand there is a difference in sciences. I think we have to tell them that. I think they think science is science, and that until I classify that as biology or chemistry or physics, they don't get that.

Summary for Patricia

Patricia has been trained in medical sciences. When she began to teach, her ideas about teaching science were very much influenced by her past training and work in science. She talks a lot about her training and interest in chemistry. Chemistry seems to be the foundation for her ideas about what is a core area of science that connects to other areas. She teaches a coherent science program as shown by her SMS diagram and as discussed in her interviews about how her curriculum fits together. Other areas of science are included in various ways in her classroom and curriculum.

In the time she was observed teaching, Patricia demonstrated that her beliefs about the connections in science are applied in her teaching. Her unit on evolution included chemical, physical, geological and biological concepts. She used the word connections when describing science in many of her statements about her teaching in her second interview. It is clear that Patricia believes that science, as a discipline, is a connected field of study. She translates that belief into her teaching.

She does not like any existing textbooks so she develops her own curriculum. The curriculum strongly reflects her beliefs, as it is not based on a textbook. She uses many resource materials, and has freedom in developing her curriculum. This could lead to an incoherent curriculum. In her case, she seems to have the larger picture of how her science curriculum builds over time and progresses conceptually for her students.

Coherence in her curriculum is evident from how she talks about it and from her SMS diagram. The diagram vividly shows a progression from a larger concept of chemistry as a core idea to a more specific one of human systems, with evolution, genetics and cells in between. She talked about often going back to ideas when she was teaching a concept. She also mentioned introducing ideas in order to have her students exposed to them, so that she could spend more time on them later. Patricia has taken a deliberate approach to connect the science ideas together. There appears to be a solid coherence in the curriculum she teaches.

Her beliefs about science do influence her teaching. Since she develops her curriculum, the challenge she is experiencing related to an outside curriculum influence is the state standards. She is aware of them and acknowledges that they exist, but hasn't done too much with them yet. She is struggling to figure out how they help her teaching. She is concerned that they dictate way too much content for her students, such that her students could not learn all of that content in a year. Since she does not have a school curriculum, her knowledge and beliefs affect the effectiveness of curriculum materials at the first levels of the TIMSS tripartite model of curriculum. The reference point for curriculum effectiveness for Patricia is state standards. At the time of this study, she has determined what she will and will not teach based on the standards, so that her knowledge and beliefs heavily influence her practiced curriculum. The influences of her views are much stronger than those of state standards. She admits, however, struggling to better understand how she can align what she and her school does in science.

Her beliefs about the coherence and connections of science appear to facilitate effective science instruction without the influence of outside curriculum or standards. She uses resource materials other than curriculum to build her program. The program construction she has accomplished matches well with what national standards say about a high quality science program. Patricia did not seem to be aware of those recommendations, but was able to develop her science program in the ways described by the standards describe.

Patricia demonstrates high standards for herself and her students. Her view of herself is fairly traditional in her approach to teaching and content even though her impression for content is not traditional. She demonstrates good quality content that is coherent for students within her science program and works to explicitly connect the current science topics in her class to other science topics. The relationship, between her beliefs and knowledge regarding the coherence and connectedness of science concepts and classroom practice, is strong. Her judgments about what science is and how science is connected have been consistent throughout this study. Given this analysis, Patricia is primarily a Type II teacher: content curricular focused and makes connections.

Robert: Central Valley Middle School

Introduction

Robert teaches eighth grade in Central Valley Middle School in the rural western region of Maine.

Academic and Professional Profile

Robert was interested in science since early in his college years. His educational background includes two years in a pharmacy program at the state university. Then he transferred to another branch of the university and changed his major to education. This switch occurred when he realized he didn't really want to be a pharmacist. He has almost completed a Masters of Science in Teaching from a college in Vermont. In this Master's program, classes offered were all science classes. Between the pharmacy degree program and the Master's degree graduate program, he has taken four years of science courses. He did receive some education training when he switched his major.

He stated that he has a strong and extensive background in science, which has helped him to have the confidence to teach science at the Middle School. He also coaches the school's Science Olympiad team. He has been quite successful with his Olympiad teams, winning a state competition and traveling to the national competition.

> *Having the extensive background in science has helped. I have worked and coached the Science Olympiad team. In twelve years we won the state championships and have gone to the nationals with teams from all over the country. That has been great experience to see teachers from all over.*

To keep current in science education, he attends conferences and workshops regularly. He finds this valuable and enjoys attending them. He has found a group that conducts science education programs; he has followed and attended different sessions of their programs. He actively works to stay current in science and science education.

Class-Specific Perceptions and Concerns

Robert is happy with his teaching situation at Central Valley Middle School. In his discussions about his classroom and teaching, he revealed that his struggles are with

designing the best program for his students. Issues around curriculum materials are not a concern as he has high quality science teaching materials. Discipline also doesn't seem to be an issue.

Robert does make all curriculum decisions and uses a textbook as the guide for his curriculum. He is pretty satisfied with the textbook, but would like to make some changes. For example, he would like to have or build in a spiraling of concepts to be returned to and expanded on rather than doing a topic just once. He realizes that he needs to give more time to certain topics than the textbook does and worries about things that are left out or skipped.

> *A lot of my stuff is from a Prentice Hall series and what they have is a set of books. The series we get our books from is fifteen or twenty some books so each one covers a small topic. So we have an evolution book, they have a forces, motion and energy book. And that is the one we are using now. We follow the book quite a bit. We don't cover every chapter. A lot of time I go in more depth, and some things I skip over.*

He used to teach only earth science but recently he worked to establish a curriculum that is more integrated or at least exposes students to various science areas each year in the middle school. As a result, he feels that he needs to cut back on the number of topics. In a process that involved aligning the curriculum with the state standards, he realized they were covering too many topics and they needed to slow down.

> *Once we changed over, I taught out of the book. We taught twenty some chapters before and we were always trying to get through chapter fourteen.... When we cut back on the curriculum, I just picked out the areas we were covering in depth.*

He uses his current textbook as the curriculum guide and the curriculum. The textbook provides the sequence of topics. He extends the time spent on a topic much more than the textbook suggests, but uses the topical sequence from the textbook. In class, he had students read from the book and do questions in the textbook.

> *I might assign them a reading assignment. They are pretty short to read two to four pages about forces and then there will be three to four questions. And then they come in the next day and they would have a basic understanding of.. and within about two minutes I can tell who has read it*

and who has not without a quiz or anything just by discussing it.

When asked about whether the textbook influences the way he thinks about science or teaching science, his response indicates that it does affect his thinking about science more than science teaching. It is difficult to tell how much it impacts this thinking as it might just be noting new ideas.

I don't use the teacher's manual, I use the student book. The teacher's manual will tell you how to teach and what to teach. I like it better to go with what works for me and certain questions I like, and what to ask. Occasionally I will look at it, but it has been a long time since I have looked at a teacher's manual.

He seems to have developed a style or approach to teaching that he thinks works for his students. His use of the textbook is for guidance and background support for his teaching, and sometimes for activities right from the book.

There have been middle school science textbook analyses conducted, and the results posted to various educational sites. He was aware that the textbook he uses for the eighth grade has mistakes in it, but he didn't seem concerned about the potential errors.

This one [his textbook], I saw that they [the reviewers] found lots of mistakes. I haven't found many. A lot of them might be small. Not big major errors.

One of his strategies for keeping students interested in his class is something he calls a brainteaser. The idea came to him when he first started teaching and was concerned about discipline and students staying focused on science. It has grown and evolved into a part of every week. He has several categories for these short instructional units. They might be trivia or mystery questions and they can last from three to 15 minutes in length. He uses them at the beginning of class.

At first it was just to try to get the kids to focus. It was designed to draw kids in. But then on the trivia days it was really neat and in ten minutes I could give them a biology lesson, some astronomy.

These mini lessons include different topics and sometimes are a problem solving question. When asked about how these teasers fit into his curriculum topic sequence, he was not concerned with how they connected. He sees the activities as enriching and helpful to students in seeing an application in science or a new aspect of science.

No, I don't even worry about that, as long as I cover [the curriculum], the trivia is really hit or miss. Some of it might hit upon this and occasionally we do ... a lot of those questions are hit during the year. But I don't go through and make sure we are doing physics trivia when we are doing a physics unit.

The purpose for doing these activities is to show students a variety of science and how it fits in the world. He does not explicitly link these teasers to what he is doing in class.

Another teaching strategy is to find ways to help students to see science as being all around them. He does a lot of demonstrations and hands-on activities in his class. The labs observed in his motion unit have, qualitative and quantitative parts. The qualitative part is to help students see the concept working. The quantitative part helps measure and make predictions by knowing the principles and how to calculate them.

Yeah, I try to have a rationale behind things to show them how it ties in. What we do in class is always part of the bigger picture. It is not just for high school and science ends when you leave the science class. It goes on all the time and I try to make sense of it. I want to teach students that science isn't this foreign entity and it is a part of their lives and their being, the way the world works around us, their body and all the things we study in science. Science is also a process of how we do things. Logical ways or the scientific method.

The state and national standards have had an impact on what he teaches in science. Robert is familiar with the documents and recognizes the changes he needs to make. One change he feels good about now is spending a lot more time covering much less material. In the past, he said he might spend a day or maybe fifteen minutes on a topic before moving on. Now he will spend a week or more on it. He had been working on - the motion unit - the entire fall.

The whole fall was forces and motion. The first unit was on velocity calculations and momentum. Then we went into forces in fluids so we did buoyancy. Every unit they have had formulas and calculations and it has been pretty abstract.

Robert is making changes as he thinks he should based on standards and he has a good solid program grounded by the textbook. He feels like what he is doing is helping his students learn science. His students appear engaged in the science he is teaching.

Classroom Practice

This section describes what topics were covered and whether they were connected to other science topics as observed in the classroom. The information includes the data from the observation instrument, instructional materials, teacher and student handouts, and researcher notes from the observations. A unit on motion was observed in Robert's classroom, and was a continuation of a longer unit, so the observed unit was in progress when the researcher started the classroom observations. It was intended to last another several weeks after the observations.

The researcher observed the portion of the unit about simple machines.
The focus on motion during the classroom observations can be seen in Table 8. Few attempts were made to connect the motion ideas to other science ideas. The observations indicated that Robert keeps his curriculum focus on motion. The lessons observed were crisp, well organized and did not wander from the specific topic area. Any connections that were made were located in the mini-lessons. If one of these mini-lessons was long enough, the content was recorded as a part of his class instructional content practice. Overall, the mini lessons did not include a large variety of sciences.

Table 8: Robert - Science Content

	Number of records	Records in areas within those Benchmarks
Nature of science, common themes, and habits of mind	19	4 of 13
Other stated content curricular Benchmarks	136	3 of 7
Non-stated curricular Benchmarks	19	5 of 15

When examining the variation of topics within the content areas I found that Robert made only a few connections to other topics within and outside his topical area. For example, in his motion unit, links were not made to other Physical Science topics. Robert presented only three of the possible seven topics areas listed under the Physical Setting Benchmark. This is a lower amount of connections within topical Benchmarks than was found with the other observed teachers. Within the non-stated Benchmark coverage, he discussed only 5 of the possible 15 science topics within those Benchmarks. Most of the connections were made in the mini-lesson activities. This pattern of low

number of connections indicates that he stayed focused on the specific science content he was teaching.

Regarding the content connections made by Robert as compared with those connections of motion and forces in the Project 2061 Atlas of Science Literacy (AAAS, 2001), both had few connections. The possible linkages in the Atlas of Science Literacy to other science topics within science at the grade 6-8 level include gravity and the movement of the solar system. Robert did not specifically mention gravity as a part of his lesson, nor did he make any associations to planetary motion. Robert's limited connections in this unit, and the smaller number of connections in the Atlas might indicate that this content area is difficult to connect to other areas of science. This conclusion makes it more difficult to definitively determine whether more connections could have been made and hence whether Robert teaches science in a connected fashion. However, in the classes observed, the science topics that were related to other science areas were most often the mini lessons. Robert stated that these mini lessons did not need to be connected to the larger lesson. This apparent singular content focus of Robert's larger lessons indicates that he may not teach in a connected fashion.

In summary, Robert made little effort to make connections to other areas of science during the lessons observed. The focus and pace of his class while working on the content indicated an intentional and purposeful classroom practice. He was focused on helping his students learn how to manipulate the equipment and to quantitatively measure forces in the lessons observed. He would often return to a skill or procedure if his students seemed to be having difficulty. The speed with which he covered the topic did not seem to be a concern for him, although he did say he was worried about getting behind in his curriculum sequence.

Self-Described Subject Matter Structure

Robert's subject matter structure (SMS) was exemplified by what he said in the two interviews, by his concept map diagram and his statements from the survey. The factors involved in determining his SMS are varied but mostly relate to his background in science.

Robert has been teaching long enough to know many ways to keep eighth grade students engaged in his class. He often revised lessons and approaches to a topic based on what students learned and how involved they are with the science topic. His knowledge of science and his experience in teaching science seem to define his SMS.

He talked about the sequence of the science content he taught in the observed lessons and why it worked in that sequence.

The advantage is that it follows a sequence. I think it goes from less difficult to more difficult. Disadvantages. No, I didn't notice any disadvantages. I haven't always done it in this order I changed too... based on what I have seen in prior units and then seemed to work out. I didn't do labs on third class levers and wheel and axle. It is the same concept. It is just harder for them to take the measurements. Once they have the measures of the force, then the calculations are all the same.

He believes that it is important to help students understand simpler ideas and to then build on those ideas. His sequence of science units is based on what students need to know and in that order. The depth with which he goes into the content is more difficult to determine. He has modified his unit to exclude some topics, i.e. third class levels. He also talked about his introduction of qualitative labs.

These labs give student the materials for a lab to use to either discover the function of the materials or how, in the case of simple machines, they made work easier. With the explanation and discussion by students, these could take almost two full classes. These qualitative labs were not collected and graded. After these labs, students conducted quantitative labs where they had to numerically show the benefits of the machine. These were collected and graded. Robert talked about the qualitative lab as a way to help students first understand the benefits of the machine before doing any calculations.

Weather was a factor for Robert in planning his sequence of content. He has changed the sequence of topics to allow his students to get outside. He saves the other units that don't need to be done outside for the winter months.

The reason I do the physics first has to do with our climate... Because several of our first labs are outdoors. Instead of pushing a cart across the floor here and calculating velocity, I take them out in the parking lot and have them bring in

bicycles and skateboards so they can relate it a little bit more to what they do. It is the same order as our textbook. But logically it goes from a lot of the stuff that is used later on. Like for instance forces. You need that concept to move into momentum and velocity.

There was coherence to the ideas and topics of the units and lessons Robert taught. This indicated that he is thoughtful about what and when he teaches. He talks about the coherence of his curriculum in the context of the simple machines unit.

[Students] should have an understanding of what simple machines do. And the one big thing out of it all is the mechanical advantage part of it. How we are able to take and use it to apply a force of a machine and that machine will multiply that force.... Efficiency is one I don't worry about too much.

Robert makes some effort to connect his science to the real world. The examples he gave were often automobile oriented, but he still used real examples. Sometimes he would start a unit with a general problem to hook students into the topic, or he would develop an application for the conclusion of the units. One thing he said he would like to do is build a ceiling pulley system so he could lift very heavy objects to show students the power of simple machines.

He has high expectations in science for his students. He expects his students to understand both qualitative and quantitative aspects of motion. He spends a great deal of time on the topics. His tests are comprehensive and ask challenging questions such as having students calculate the mechanical advantage for various machines. His expectation is for conceptual and functional understanding of motion.

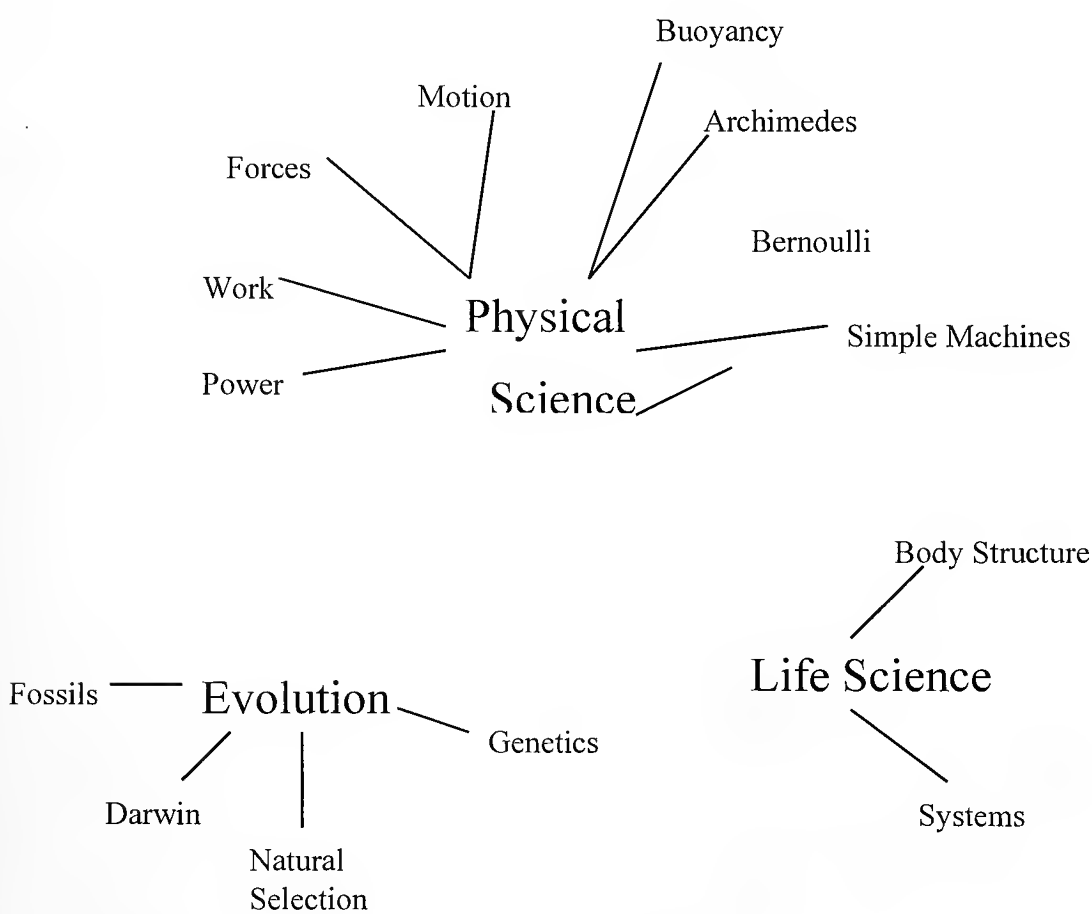
I could give them a final exam on all of this and they would be able to do all the calculations like mechanical advantage, efficiency and remember to put force over force. Another thing that they should know is forces, They should know the effects of forces pretty well, the effects of friction and mechanical advantage. That would be the best-case scenario. I would be totally satisfied with the minimal part and most do pretty well with that.

When asked how his students did on the test at the conclusion of the unit observed, he said that they did very well. It actually was a surprise for him as to how well they did on the test.

Robert's SMS as diagrammed helps illustrate how he thinks about the science he teaches. He outlined three distinct areas of science and then components of each.

Robert was asked to make two diagrams, one prior to classroom observations and one after the observations. He was asked to do this as a check to see if participating in the study had an effect on his thinking about the science he teaches. The first one is simpler in topics than the second, but they exhibit the same patterns and groupings of topics. Close similarities are evident, so his thinking appeared not to change during the period of the study.

Figure 5: Robert: SMS Diagram - Prior to Classroom Observations



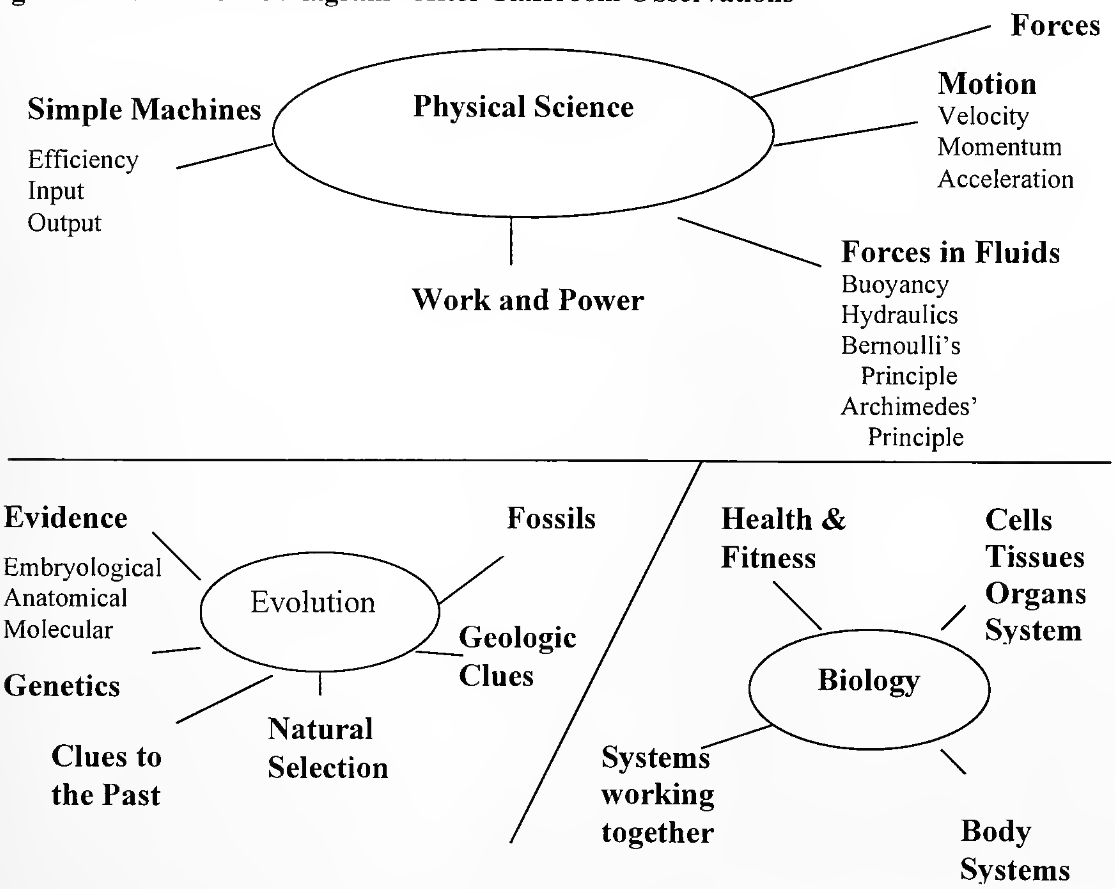
In the first SMS diagram, Figure 5, he has three distinct areas of science: Physical Science, Life Science and Evolution. It is interesting that he separated evolution as a

distinct area of science from Life Science. Within the subtopics, he lists mostly life science topics except for fossils. It appears that Robert thinks of the science he teaches as separate units and maybe separate areas of science.

In the second diagram of his SMS, Figure 6, there is little change in his thinking. What he did do the second time was to include more detail about the subtopics he teaches. He also drew a line between the science areas making them distinct from each other.

In this diagram, he lists only two life science topics under evolution. The rest are earth science topics. It may be that he thinks about evolution as being more of an earth science topic or least the evidence for it, rather than a life science topic. Maybe this is why in both diagrams he has evolution as a separate topic of science with no connections between it and the life science topic area.

Figure 6: Robert: SMS Diagram - After Classroom Observations



His beliefs and thinking about what he teaches appears to be consistent over the period of the study.

When asking Robert about his thinking about science on the survey and in the second interview, a different picture emerged. On the first survey he selected the response: *It is best for students to learn science in the real world context such as reproducing phenomenon in experiments so they see the science concept represented.*

This indicated that he believed that science is a connected discipline. When he responded to the first survey question in the interview, he was not sure of how to respond. He talked about many other things. When he was again asked, his response was general with the inclusion of information about his curriculum and his process for its revision rather than selection of one of two choices in the question.

> *The way we got the unit in the district is we made and filled out all of the Learning Results and filled out the gaps. That is how evolution came to this level, so I scaled back some other areas that were already done in the lower level like rocks and minerals and things. So the physics came through after that. The length happens because of the volume of material.... Now we are doing evolution and not so much lab stuff. Not so many labs, a few. The nature of it is different.*

For the second question on the original survey he selected, *"Students should focus on an aspect of science while the teacher illustrates connections to other science areas such as biology, chemistry and physics not studied at that time".*

When he was asked to select again in the interview, he was not able to clearly choose. He was troubled by the question, which seemed difficult for him to answer. His responses for the survey questions indicate that his beliefs are not stable as to whether science is a connected discipline and whether it should be taught as such.

An area that he was able to respond to more clearly was whether state and national standards have affected his knowledge about science or his teaching of science.

> *I don't think so, not the knowledge. I think I have a pretty broad knowledge base. Maybe specialize a little more. Instead of covering a lot of material and going right through it, we spend a lot more time covering much less material in more time, so my understanding in a particular area, or an understanding in a way that allows me to teach it could improve in some ways.*

Robert was also was asked whether his background in science affects how he teaches science. He acknowledged that it does affect the way he thinks about the world and his teaching of science.

I think you see the world in two different ways. I can't touch a doorknob without thinking about the physics behind it. When I see boats in the water I think about why they are floating and the different forces involved. Yea .

Robert SMS appears to be consistent during the study. What he thinks about and the science he teaches stayed the same, but his beliefs about science seem less stable than the way in which he thinks about the science he teaches.

Summary for Robert

Robert's beliefs about science and the science he teaches are characterized by some uncertainly. Robert's ideas are similar to Daniel's ideas in that what he thinks about the science he teaches is solid and consistent. At the same time his beliefs about science as a discipline seem to be unclear and were not strong enough to be consistent through the study.

Because of this divergence in his thinking, Robert doesn't seem to have a strong sense of science as a connected field of study. He does believe that it is a coherent field of study. His science teaching indicates that he believes science is comprised of separate areas of study; or, at least he sees this as the best way to teach science. It is possible that his separation of ideas is a result from the idea that they are separate curriculum units and therefore he drew them separately in his diagram. He exhibited a very focused instructional pattern that did not connect the science he was teaching to other science areas.

Robert's beliefs about the coherence and connections of science don't impede science instruction in the unit observed. It was difficult to determine whether more connections would have facilitated better learning of the physics. Perhaps this is due to the fact that Robert was focused on what his students should know and be able to do and he worked hard to ensure that they knew those things.

An interesting aspect of this study is how Robert's knowledge and beliefs impact the effectiveness of curriculum materials in the TIMSS tripartite model of curriculum.

Here Robert has mostly used the curriculum about science, his textbook, as it was intended. This shows that his beliefs have not affected the implementation of science in the curriculum as articulated by the TIMMS model. At the same time, his beliefs about science teaching did influence his teaching and hence the TIMMS model of curriculum.

He believes that science builds on itself and that students need to know certain ideas before others. They also need to experience science ideas several ways before they begin to understand the concept. So instructional time on the concept is a factor he has extended beyond the textbook. He uses science sequence in textbooks as his topic sequence, but modifies the depth and breath of the textbook. His beliefs about science teaching have affected the implementation of his science curriculum.

The connections within science were not a concern, even when he conducts the mini lessons. These do cut across the discipline of science, but their coherence with the unit he is teaching was unimportant. These mini lessons could have helped him to introduce students to other sciences beyond what was in his curriculum. In the observations, these mini lessons provided connections within the sciences, but he didn't recognize them as serving that purpose.

What is the relationship, if any, between Robert's beliefs and knowledge regarding the coherence and connectedness of science concepts and their classroom practice? His beliefs about science as a discipline seem to have been provided by his background in science. This doesn't seem to affect his thinking about the connectedness of science. He does not seem to believe that there are connections within science as he did not talk about them, and he did not incorporate those connections in his teaching. The factor that does influence his teaching of science is his beliefs about the learning of science by his students.

He does think there is coherence to science. He talked about that coherence and what he does to help student understand science. The coherence for him does not include connections within a science area.

The aspect that is difficult to determine is how much of his science background affects his thinking about why science is not connected. It is to hard to determine with this data, but perhaps his science background was in courses and that they presented the

content as isolated topics and there was no emphasis on the connectedness of science. Given this analysis, Robert is primarily a Type I teacher: singularly content focused.

Celeste: Oceanside Middle School

Introduction

Celeste teaches sixth grade at Oceanside Middle School in a coastal community of Maine.

Academic and Professional Profile

Celeste's background is different from many public school teachers. She has a Master's Degree in environmental education and an undergraduate degree in environmental science. She feels well prepared to teach middle school students. She said this gave her a bigger picture of science than a teacher who was specifically trained in one area of science. Her husband is a scientist and she counts on him as a reference for what a scientist does. She reads books about science and attends workshops to learn about new science. Much of the learning she seeks for herself is in science teaching.

> *I feel I am a generalist and at times I don't know certain information. I also feel that if you know or if you were specifically trained in one area of science you could do that much better than I could, but you would not be able to do a lot of the other things or you wouldn't have the bigger picture. I don't want to necessarily be that way, but there are times when I don't know certain things about science that I feel I should know.*

Before beginning her formal teaching career in public schools, Celeste was an environmental educator at an Audubon facility and a national research reserve for 12 years. One of the things she says she learned there is a curriculum model called the 4-MAT. She developed a curriculum using this model that was widely used in Maine about the natural systems of the salt marsh. This curriculum development process has influenced how she thinks about teaching science, and she uses the techniques today in her current teaching situation.

I think not all students learn best in one way. And I developed that [curriculum] program with the Bernice 4 –MAT model and after reading that book and a couple of her other books, for that very reason. There are some kids who are oriented to learning in a hands on way... But there are some kids who learn a lot by sitting reading books, and can learn a lot of science that way. And might also ask questions about the world... So I guess in teaching science... the units that work well are the units that I have pieces for a variety of different types of learners.

Celeste is comfortable in her classroom and interacts well with her students because she has worked with children and science for many years. An example of her use of the 4-MAT instructional approach and how her students respond was an introduction to cycles she led with her students. She had her students lie down on the floor of the classroom, close their eyes and visualize something as she read a passage to them about the cycle of the seasons. The students shared the images they saw in their minds with the rest of the class. She is well organized in her classroom instruction and her students respond well to her and to the activities she uses.

Class-Specific Perceptions and Concerns

The issues that concern Celeste about teaching science are focused on how to increase student learning, create better assessment techniques, and balance her content ideas for those in the standards. Topics such as discipline and instructional materials did not come up in her interviews. Her struggle with national and state standards is that she doesn't completely agree with everything in them. At the state level, they have created an incentive to teach from them because they represent the content that is tested. This is troubling for her, but they have also made her focus on specific content to teach, which she wasn't sure she would have done without the standards. They have raised the level of rigor in her classes. Part of her struggle with standards is the transition from teaching in informal education settings to public school teaching.

She hasn't known teaching in public schools without standards. From the beginning of her formal education training and teaching experience there have been

standards, and she doesn't know what it would be like without them. If there were not standards, she said she is the type of person who would only teach what she loves.

> *It is a little hard to tell. This is only my sixth year of public education being involved in that. And during that time the standards have been a piece of those five years. So I don't know how much of it is the standards themselves or how much it is becoming more experienced at teaching in the public setting. Or how much of it is just the expectation of the school system....*

For instructional materials, Celeste uses multiple instructional resources. Textbooks do not play a big role in her curriculum, but they do provide a basis for the sequence of topics she teaches so she sometimes uses them for her grade level. Mostly the textbook is a resource such as reading materials or for pictures of things to support what she is teaching in class.

> *The textbooks are supplementary materials. We use Prentice Hall.... They have beautiful pictures and mostly totally accurate information. They are small, so you can put them in your backpack and carry them around. We have three of them. We have one on Ecology, one on Earth Science and one on Evolution.*

She is concerned about the science and how the science is presented in the textbooks as she said the way the science content is covered in the textbooks is trivial. She thinks the textbook authors simplify ideas too much so that it becomes difficult for students to learn from them. They use vocabulary as a way to cover a topic and not examples or activities to learn about concepts. She finds it difficult to teach in any depth about a topic using the sequence in the textbooks.

> *[Textbooks] are good because you can get a quick bit of information, but they are bad because of the boiled down nature of them. They are often talking about a very complex subject and then they put tons of vocabulary in there and they boil it down to a page and a half, which could be a whole library of information. And sometimes that confuses kids because they don't have, or if it is something they have some prior knowledge of like ecology... so boiling it down makes it really hard for kids.*

Because of her use of the textbook and her own interest in having students learn science from various perspectives, Celeste struggles with providing a sequence of ideas

that will help her students learn science. She can't follow the pace in the textbooks because it covers materials too fast, and she uses other activities to support the learning of concepts so that her units last longer. To know what to teach for all students is a challenge because there is so much. The question of a coherent curriculum is something Celeste is working on.

> *A lot of times you take a big thing and make it short ... assuming that they know about matter or know about this or that. After a certain number of years of teaching, you know which things they are going to come in knowing and which they are not. It is a constant juggling act to try and decide if everybody should know the same thing and start from the same place or if they can just learn about their one little cycle and not get into what matter is.*

Celeste works hard to present science for her students in a variety of ways so that they learn the science and are excited about it.

When Celeste was asked about whether the textbook influences her thinking about science, she explained that they have helped provide a context for the science. There is a major weakness in that they simplify the science so much and move through concepts assuming students know them already. She does think the textbook has influenced her science teaching.

> *Sometimes yeah. I think sometimes it adds a perspective I wouldn't have had otherwise or some information.*

She would like more flexibility in her curriculum. She said she would like to ask her students in the beginning of the year what they are interested in learning and teach that. She thinks this would help them become more engaged in learning if the topic was something they selected. She also would like to do more inquiry type activities to help her students learn about the excitement of discovering things in science. The most frustrating thing for her is that all of her teaching outcomes are predetermined by the standards or school curriculum. She finds this restraining.

> *When I focus specifically on the book, that is all they get. And there have been times when I have seen myself do that. If you are teaching a chapter out of the book and you are not supplementing it in any way it is limited.... I think it makes*

more sense to do some reading, some watching a movie, some going out and doing stuff.

This struggle between what is predetermined either for the textbook, curriculum or standards makes the development of science restrictive for Celeste. This is not all bad as she says she might just teach whatever she likes and that might not be all that helpful to her students. Her informal education science teaching has given her a base experience that is flexible and creative, which she seems to sometimes struggle with in the public school setting.

Classroom Practice

This section describes what was recorded from the classroom observations in Celeste's classroom. The sources include the observation instrument, instructional materials, teacher and student handouts, and researcher notes from the observations. Most of the unit on natural cycles was observed by the researcher from beginning to end.

Celeste's classroom is active with much student autonomy. Celeste conducts a well-organized class, and her students know what they are to do and how to work well independently and in groups. They were often working in groups on projects or presentations.

Table 9 shows the science content presented in the observed classes. Celeste mostly focused on the discipline topic she was supposed to teach, staying true to her curriculum. At the same time, she made connections to other science areas at a much higher rate than the other teachers in this study. The connections to other science topic areas occurred both in the Nature of Science, Common Themes and Habits of Mind and non-stated curricular areas. She made every effort to help students with their questions, but would redirect issues if they were not directly related to the topic of the unit. When she detected a lack of background knowledge in her students, she seemed to find ways to bring in the needed content if she thought it would enhance her current lesson. She didn't hesitate to spend class time on topics that were related, but not in the stated curriculum.

Table 9: Celeste - Science Content

	Number of records	Records in areas within those Benchmarks
Nature of science, common themes, and habits of mind	66	10 of 13
Other stated content curricular Benchmarks	116	4 of 6
Non-stated curricular Benchmarks	55	9 of 24

It appears that her connections to other science areas were intentional because she connects to other areas approximately 50% of the time, and also incorporates the foundational concepts of science from the Nature of Science, Common Themes and Habits of Mind. She made these connections more frequently than most of the other teachers in this study. Yet despite a variety of connections, the spectrum within those connections was fairly narrow. In other words, she connected to the areas that were closely related to her classroom topic or within the benchmark category, and not to just any area of science as it came up in class. The connections in the non-stated curriculum, although fairly high in total records, were fairly low in the possible areas within the Benchmarks. There seemed to be purposefulness to the connections.

Comparing the connections that Celeste made with those in the Atlas for Science Literacy (AAAS, 2001) the grades 6-8, revealed many similarities. Celeste referred to atoms and molecules, chemical reactions, conservation of matter, inherited characteristics and systems from the three other Benchmark categories, and these were the same ones shown in the Atlas. As an example, she introduced the concept of cycles, and as an overview she asked students what they knew about cycle of things. She recorded their ideas and those ideas that made sense. If an idea didn't make sense she would press the student for more information until she knew whether or not the idea was related. At one point, a student mentioned the word matter. She then asked the class if they knew what the word meant. No one answered. She then went on to explain what matter was for the rest of the class. In this one observation, she moved from the concept of cycles in general to the topic of matter and atomic structures. She later reflected on why she did this.

That is always a big struggle isn't it? I remember starting out the unit. There were different cycles of things, there were cycles of matter or of natural and living things. Then I remember thinking I have never taught them what matter is and I

am sure probably half of them know and the other half don't. So what good is it talking about a cycle of matter if you don't know matter. I remember ending up spending a whole lesson asking what do you think matter is and what do you know about matter and trying to get them to basically understand that concept when it really wasn't written in the text.

She believed that students needed to have an understanding of matter before they could think about and learn about cycles because so many cycles were cycles of matter. Celeste made an on-the-spot decision to alter her lesson plan.

During the observations, Celeste's students made two presentations. One was a role-playing activity and the other was a unit summary assessment. Celeste worked with students on the content by explaining how to present an argument and explain their case. These skills connect to the communication topic from the Habits of Mind category in the Project 2061 Benchmarks.

There is a possibility that the number of connections to other science areas made in this unit may have been greater because the topics of Ecology and Cycles lend themselves to making a greater number of connections. Because Celeste made connections to Physical and Earth Sciences and the Nature of Science, Common Themes and Habits of Mind categories, it is possible that these connections might have been intentional, and not just because of the content topic. The evidence of her making connections as well as her own articulation about the connections in science from the interviews make for the case that even though these areas may be more easily connected to other science areas, she made the connections purposefully.

Self-Described Subject Matter Structure

This section outlines Celeste's thinking about science from her interviews, concept map, science she teaches, and a review of the survey data. Celeste is philosophical about her teaching and what aspects of it are important to her. She also is willing to rethink and try new things, as long as they make sense to her for improving the learning of her students. She thinks deeply about science and what she brings to teaching science. Thinking scientifically is the process of doing science that she says is peculiar to science.

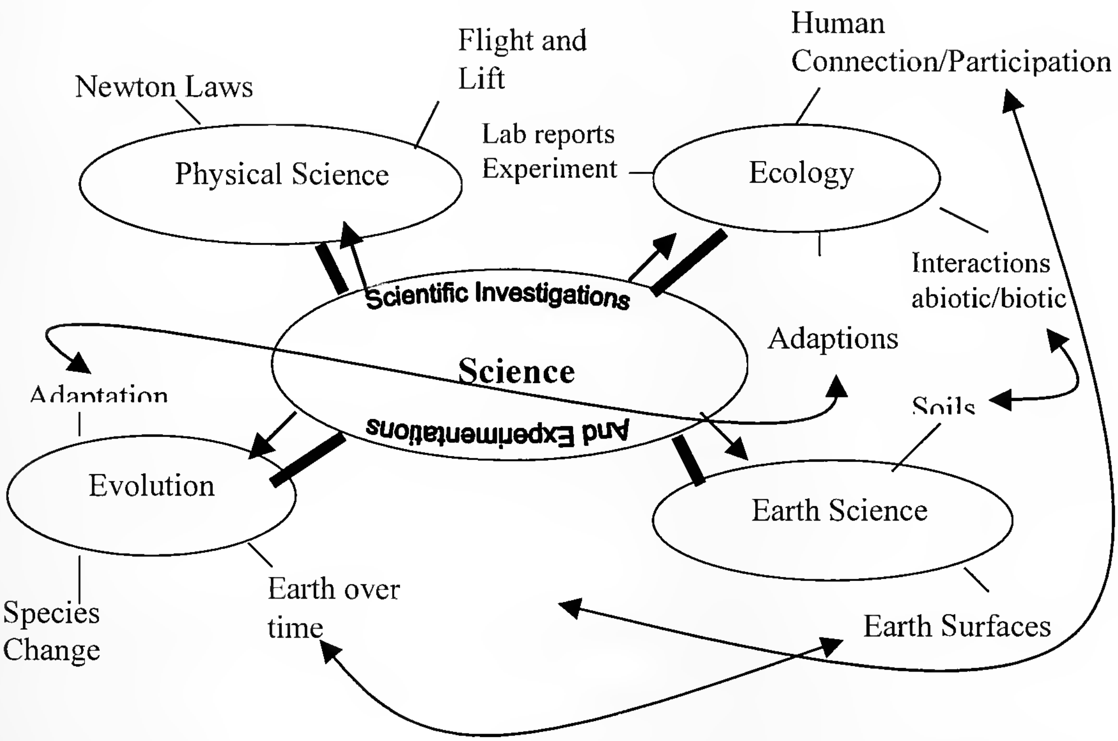
I believe that science is the way the world works around us, but that it also is how we choose to learn about that world around us. If you are studying philosophy, you would go about learning about that in a different way than you would learn about science. There are structured ways that scientists or we choose to learn about the world. The processes of science are really important to the actual learning of the world.

When asked about why she conducted her lessons in a particular order, she talks about building knowledge. Her plan was to provide a general set of ideas first and then move into the specific areas of science later. She strives to build in a coherence of the science learning for her students, and works to provide sequences and type of activities that expose students to various ways of learning. She is deliberate about what is introduced in her class.

I did them [the lessons] in that order because I wanted to give all kids a general sense of a variety of natural cycles. We had a text that gave an overview of natural cycles. And we went through the text and kids did some work on their own and we did a couple of worksheets and a couple of discussions in small groups. And then the kids chose one particular cycle to focus their studies on.

She seems to uses projects as a way to end an instructional unit. These projects included presentations to the class. She was specific about how the students' were to present to the class. Communication skills in science came though strongly.

Figure 7: Celeste: SMS Diagram - Prior to Classroom Observations



Celeste was asked to complete two SMS diagrams, one prior to the classroom observations and one after. The two diagrams look different. Looking more closely at them, the content is similar in both, while the differences are in how she visually presented the science that she teaches. One is a concept map and the other is a Venn diagram. I think participation in this study encouraged her to think about what science she taught.

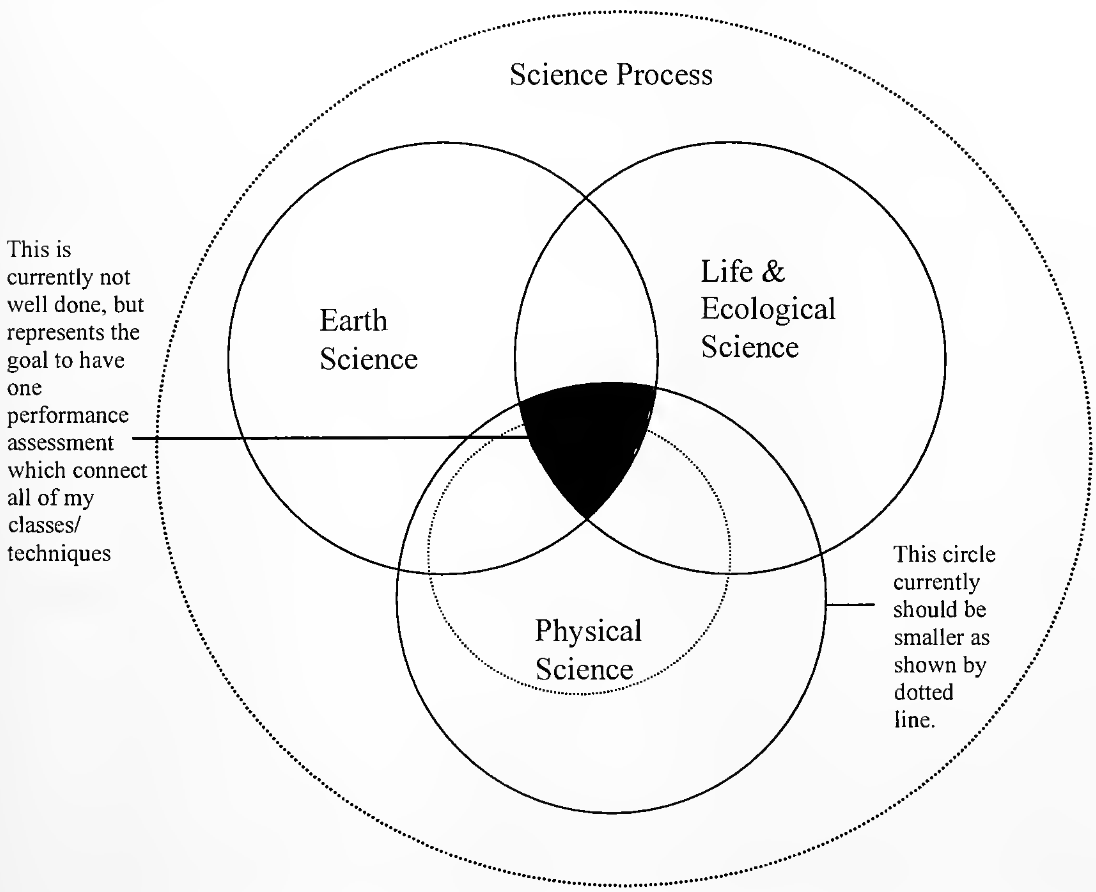
Celeste said she didn't really have the time during the year to think about the science she taught in terms of the questions asked and the diagram she drew in the interview. She felt it was good for her to reflect. The extent to which she changed her thinking is hard to determine. From looking at her diagrams, it appears that what she did was to refine her thinking about the science she taught and to illustrated it in a slightly more organized fashion. The first diagram includes all of the components of what she teaches, but is fairly complex with lots of arrows making connections between topics. The second diagram appears simpler in that she drew several Venn diagrams that

encompass all of the topics so that there was no need to draw arrows. She explained that her second drawing is more sophisticated in that the connections implied in the Venn diagram overlap, whereas in the first drawing the connections are drawn with arrows.

She talked about the second diagram as being more representative of her teaching. In response to a question about the overlap of content areas in her second diagram she stated that throughout the year there should be a conscious effort to teach physical and life sciences and how they interconnect.

> *Well, I think it makes most sense to teach all sciences all years. Currently we teach physical science only in eighth grade. I actually do a little with roller coasters and a little bit with verticopters, so I do some physical sciences. And I have done pendulums in the past as well. Each of those that I choose to actually teach a particular science process as content·*

Figure 8: Celeste: SMS Diagram - After Classroom Observations



Another method in the study to determine if her thinking had changed during the study is how she responded to particular survey questions. Her beliefs about learning science and the connections of science were stable throughout the study. When asked the survey questions again her responses were similar to her first. Her response on the first survey question about learning science was the following: *It is best for students to learn science in a real world context such as reproducing phenomenon in experiments so that they see the science concept represented.* When asked which answer she would select in the second interview she responded with the same answer about the real world context. It took her a long time to make the choice indicating that she wasn't clear about why she was choosing that selection. She went on to explain her choice.

> *It has more to do with the way I think about things, not necessarily what's the better way to teach things. That is the way I learn. I always learn better when I am making connections to things as opposed to learning things in isolation. I think it is no accident that I chose a major that makes connections as opposed to choosing one strong focus in something.*

She used the word connections in her response. It was not a part of the question's answers indicating she interpreted the question to imply making connections.

For the second question in the survey she responded students should,

Learn about science in an integrated fashion to gain insights into the breath of science and other fields and not focus too long on particular areas of science.

This answer was not a choice in the second interview. There were only two choices in the second interview to force the participants to select between an answer that supported the idea of connections or not. The response she selected was the one that emphasizes the connections among the sciences rather that the one that has students learning science in separate topic areas. She added some of her own thoughts about science and the learning of science.

> *I agree that we are learning more and more about the world and that causes us to focus on narrower and narrower aspects of science, but I don't believe science itself is an ever changing discipline. I mean the way we doing science and the focus of science is changing and that we are using more sophisticated equipment*

> *but it is basically the same process. You discover things by accident or discover from years of focus study...I think a good teacher could do either of those ways.*

She emphasized the way we do science and not the changing content of science. She is happy to be teaching sixth grade as she implied. In upper grades, she would have to be more specific and perhaps teach science in a more isolated fashion. She went on to explain her thinking about science and her teaching science in the context of the unit that was observed by the researcher.

> *Like when I was teaching cycles I taught the rock cycles and the different life cycles and ecological cycles like succession and then there were physical cycles like with matter, like I was talking before. All of those can be seen as separate things, but I was teaching cycle concept and here we are in a limited earth and these things go around and are recycled and start again. And that's sort of these connections I would think. Different kids were focused in different areas but the big picture idea of a cycle idea is the overlap.*

She was very clear about the need to make the connections in the sciences in her class. When asked whether she felt she was able to make the type of connections she was talking about in her interviews, she seemed less sure that she was making those connections and even less sure whether the students were understanding those connections. She used the observed unit to explain.

> *I didn't think I did it very well. But now when I was talking about the cycles piece, that whole idea to teach cycles instead of teaching the hydrological process, is doing that. I think I do make connections a lot when I teach.... I don't know if the kids pick up on it. Maybe that is where I am getting the feeling that I am not doing it very well.*

From the researcher point of view, her students were making the connections. When she asked her students to select a cycle to study and to present to the class for the cumulative project, they selected cycles such as water cycles, lunar cycles, season cycles, carbon cycle and even a lake succession, which really wasn't a cycle. The student choices demonstrated that a cycle was not in one area of science. When asked if she thought that her students learned better when she made the connections explicit in her class she

responded positively. She stated that she thinks that students learn better and know more about the connections than we might suspect.

Yeah, Definitely. I think they know more about it than we do. I think children can understand what they are doing.

She believes that science is the way the world works, but that it is also how we choose to learn about that world around us. There are structured ways we do science and choose to learn about the world. Knowing the process of science is really important for her, and she works to teach it to her students so that they will be able to learn about the world. In her explanation, the idea of the sciences being interconnected comes up again.

I think that because all learning is learning in small little steps toward something. That you just learn everything you learn about physical in one year. That it would be easier if there were some, like I was talking about the textbook problem, if you have some of the vocabulary then you have more places to hang the new information. Then if you are just learning it for the first time.... I think that, maybe it doesn't have to be every year you do every single thing, because it would be to watered down, but I think throughout the years there should be a consensus effort to teach physical and life sciences and how they interconnect.

She believes students learn in a connected fashion and that they could teach teachers something about this.

I think that is how kids learn. I mean kids could be teaching us how to do it. It is how you learn how to ride a bike how you learn to whatever you are learning. A young child tries something and it doesn't work and then you try a different thing.

The evidence from these sources indicates that Celeste prefers teaching science in a connected fashion because that is the way she thinks. It is her preference. What is not clear is whether her thinking has been shaped by the science she knows, how she was taught or by something in her way of thinking. She also believes students learn science best when the connections are included.

Summary for Celeste

For Celeste, the connections in science seem to be natural. They do not have to be made; they just exist and she makes them explicit for her students. She believes that

science as a discipline is connected and is not comprised of separate areas of study. She talks about how she makes her sequence of teaching coherent, but less about science in general. One theme that comes through is the process of doing science. Even with the field changing rapidly because of new discoveries, the act of doing science is consistent. The tools might be different but the way one thinks about science it similar. This is where her science background experiences and her husband's is input as a scientist seems to be influencing her thinking. She doesn't see the act of doing science as changing.

Celeste's beliefs have affected her implementation of curricula. She uses the textbook provided, but she spends a great amount of time on other topics by slowing down the pace of the science. She provides auditory, visual and physical experiences for students. She incorporates student presentations in her class so students work to develop effective communication skills. These things are not in her textbook. Her beliefs affect the effectiveness of curriculum materials at the third level of the TIMSS tripartite model of curriculum. In this case, she improves the curriculum materials to ensure her students understand the concepts before moving on to another topic.

Celeste has been in her district for seven years. Her beliefs about the coherence and connections of science appear to facilitate effective science instruction. Her students are active in her classes and work hard. Celeste teaches in a community where high achievement is important. There is pressure on the teachers to perform so that the students will do well. Her approaches engage her students and they work to succeed in her class.

For Celeste, the relationship between her beliefs and knowledge regarding the coherence and connectedness of science concepts and her classroom practice is strong. She talks about, illustrates and demonstrates that there are connections in science and that coherence is important.

Part of her past experiences in teaching in an informal science context may have affected her thinking about teaching and the important ideas of science. She does focus on her curriculum topics, but at the same time she makes connections to other science areas. These connections are made thoughtfully and they reflect areas that will offer additional insights and knowledge to the focus of her unit and are not just attempts to respond to an interesting idea or to make a connection. Her beliefs about science being

connected are reflected in her teaching. Ultimately she believes that seeing the connection is the best way for her to learn and maybe that is why she teaches the way she does.

Celeste is enthusiastic and a learner. She reflected that sometimes she would be struck during a class by a point a student would ask. She would often have to catch herself and get back to them about that topic rather than answering the question right then because it was not related to the focus of the unit. She is deliberate in her teaching. Given this analysis, Celeste is primarily a Type II teacher: content curricular and makes connections.

Tom: Kennebec Middle School

Introduction

Tom is an eighth grade science teacher at the Kennebec Middle School located in a once thriving paper mill town.

Academic and Professional Profile

Tom's education involved two areas of study: environmental science and geology. He wasn't sure what he could do with a geology degree, so he decided he would teach. He ended up graduating with a double major in education and geology. He incorporated his interest in outdoor adventures, and started an outfitter company in Maine. He has been able to develop and have a career in both teaching and outdoors adventures.

He has taken additional courses to keep up in his learning of science. One recent course was an Internet based class from a branch of the state university. He is currently enrolled in a masters degree program at a state college in another state in adventure education.

He says he is well prepared to teach middle school students. He expresses playfulness about his students. This comfort with play may come from his experience with his adventure education experiences.

I feel prepared to teach science to Middle Schools kids. I could teach high school, but I don't think I have matured much past middle school so I like teaching seventh and eighth grades. Good group. What is cool about eighth graders is that they can have an intelligent conversation with you about politics or something and the next minute they are burping the alphabet. I kind of like the diversity.

Class-Specific Perception and Concerns

Tom's concerns about his teaching are mostly related to the well being of his students and what he has and can do to help them learn science. He is realistic about his teaching situation because he has a few good science materials, and he works in an economically depressed community. He works hard to excite his students by making science fun.

He stated his goals for teaching science, which are fairly straightforward.

My goals for teaching science to eighth grade kids are that they can come out, and at least in science, that there is science in everyday life and I try to make it real.

This helps frame how he teaches his classes. He uses many examples in his class that tie science to the world. He has students make connections from the science he is teaching to the world. He believes a student's world is complex and school is only a small part of their lives. He stated that as a teacher he is competing with so many different things in his students' lives so that he has to find ways of making the science real. He feels particularly good when sometimes his students don't even know they are learning science.

Make it fun, make it fun and hands-on. You have an attention span that is about twelve to fourteen minutes. You have to make it fun. You are competing with so many different things. Sometimes I will start a class and if they are like zombies, I introduce a game. Something really stupid. And they smile and then have energy now and they are smiling. And then I can say let's go do this. It has to be fun or you are going to lose them.

The Kennebec Middle School is a very old school, and his classroom is in the cellar of the building. Even though the classroom is less than ideal, he feels that he is in

pretty good shape by having the instructional materials he needs to teach science. He said it has taken three years to get them.

> *I finally have the materials together and I feel I have some good resources now. [When] this whole weather system is up and running. It is going to change the way I teach weather.*

He has a positive attitude about doing things, but the challenge of accomplishing new things is always present. He knows when he has taught a subject too long, as he begins to be bored.

> *...having geology thrown at me last year, which is great because it is one of my loves. ... this is the first time I am going to teach it. I am still in the growth curve on that one, so I am pulling resources together. I am a couple of years from hitting boredom because there is some much I can do with that one.*

When asked about whether he has a textbook and uses it Tom talked about many other resources he uses other than his text. There is a textbook for his grade, which he doesn't much like. The district purchased it and it was there when Tom arrived at the school. He thinks the textbook covers too much science in too little time. He admits he has to focus on more than the textbook.

> *Just look at the table of contents. It is amazing. You learn a whole lot or a little bit about a whole lot of things. I don't know, somebody has to be really good to tie it all in. I am not that good.*

Because he doesn't like the textbook or at least the amount of material in the textbook, he has developed and found several other instructional materials. During the classroom observations, he used five different instructional resources to teach the unit. The activities came from the different sources.

> *Well, it is funny, I have looked at so many textbooks. There are so many ways to skin a cat (laugh). This is how I have arrived at how I am going to skin the cat. You could look at it as I am using a combination of this thing here, the sequence of that, or those new science books. I end up skipping around. It is a good book, but it is in a different order.*

He talked about some frustration with schools in general as he believes the current structure of schools of moving students around through lots of classes doesn't make a lot

of sense. He believes that no matter how liberal or conservative a school is, they are constantly trying to put a square peg into a round hole. He believes because there are so many different student learning styles that no school can meet all of those learning styles. This belief encourages his use of adventure activities with his students to keep them interested. His students respond well to him as a teacher; there was a sense of respect in the room for one another when they were doing activities.

Classroom Observations

This section describes what was recorded from the observations in Tom's classroom. This includes the observation instrument, instructional materials, teacher and student handouts, and researcher notes from the observations. Tom had a more focused content presentation as compared to the other teachers in the study.

The unit observed in Tom's classroom was on chemistry and specifically chemical characteristics such as compounds and mixtures, and how they change. The researcher saw a part of the whole chemistry unit, which lasted for most of the fall. The recorded content presented in Tom's classroom illustrates that Tom focuses on the content he is teaching and the only connections were to the Nature of Science, Common Themes and Habits of Mind Benchmarks.

Table 10: Tom - Science Content

	Number of records	**Records in areas within those Benchmarks**
Nature of science, common themes, and habits of mind	29	3 of 13
Other stated content curricular Benchmarks	120	3 of 5
Non-stated curricular Benchmarks	2	2 of 15

The activities with connections included how to conduct an experiment, to use science skills to observe phenomenon and where science ideas come from. He conducted laboratory activities and students saw the behavior of certain chemicals, and then they wrote them up in a report format. Time was also spent on reviewing the concepts in those labs.

The topic focus during the observations was limited to chemistry. In comparison with the connections within the 6-8 grade levels in the Atlas for Science Literacy (AAAS, 2001) there were few similarities. The Atlas included connections in chemistry: atoms and molecules, states of matter and chemical reactions. The other connections the Atlas made are the flow of matter in ecosystems, stars, DNA and inherited characteristics, variation in characteristics, and systems. None of these were made explicit in his classroom. The only connections to other science areas made in Tom's class were to the concept of a system and to the process of doing science.

This low number of connections was reinforced when looking at the possible variety of areas within the Benchmark. Within those Benchmark categories, he only made connections in two of a possible eleven topics. He stayed focused on his content area and when he did connect to other areas it was to a limited number of topics.

Tom did talk in his interviews about making connections in science to the world for his students, but he made a limited number of connections to other science topics in his actual practice.

Self-Described Subject Matter Structure

Tom has strong beliefs about what science is and how it should be taught. He is not clear however when asked about possible connections in science. When asked about whether he believes science is a connected discipline or not, his thinking is conflicted or not stable. At one point in an interview he states:

> *Oh, there are definitely things that are connected. That part of the challenge is keeping it relevant. Do you understand why we are studying this now? In weather, you can see and understand pressure and systems. The stuff you learned about densities will carry into all sorts of other stuff. But you have to understand what density is and matter is taking up space, having mass before you can talk about air pressure.*

He begins to talk about what he says is a core idea or a basic in science. These ideas must be understood before students can learn other things. Then at another point in an interview he begins to question the idea.

It is a tough question. It has always amazed me that the higher up in science, you know that we always see science and art as separate things, and the higher up the scale on both of them you realize how connected they are. They are not opposite at all. I think if there was something philosophical about science that is how connected it is to everything literally not only just to things around us, things like music, painting and things of that nature.

When he was pressed on this issue, and asked again about what connections in science mean to him, and where they can happen, he talked about the concept of connections and how it related to teaching when the connections in science should occur in schools.

Quite frankly I think the connections should be made in the elementary schools with a basic core you ought to be able to say okay, to all of the kids you shown them. As they get higher up in school you need to build on the basics a little bit more. I think you develop inquisitiveness in elementary school by saying look at all the different areas around us that are science and science-related. Then when you get them to be inquisitive you can narrow down the scope a little bit. And get narrower and more involved the higher up you go.

In probing more about his beliefs in science, and where they may have come from, when asked about whether a science background influences his thinking of science and teaching of science, he agrees that it influences his thinking.

I wouldn't have become as good a science teacher if I hadn't started in environmental science and geology. I think having that background was really important. You know you learn the science of things.

He also describes how he thinks about science and his ultimate learning. He has specific learning goals for his students, but he is comfortable waiting for them to grasp the larger ideas of science. In this conversation he talks about coherence to the science he teaches. The sequence he teaches does not come together until the end of the year for students.

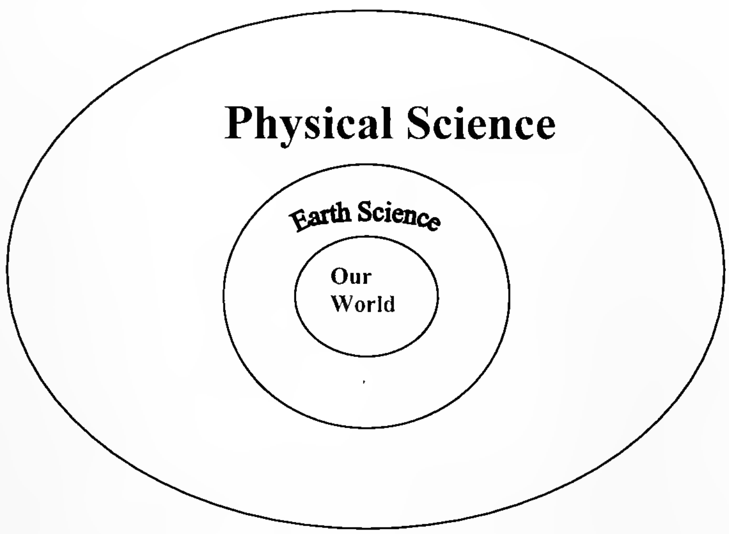
The big thing for me is the fact that they know how to balance a chemical equation and they can look around and say I understand the connection. These compounds, the matter that is around us here passes into various different forms

along the way. That is the most important [concepts] I wanted them to grasp.... That is what is nice about the way this [his curriculum] is set up. They get a base in the first half of the year then you can take it off into other areas of science in the second half of the year.

This is how he expresses the coherence in science. If students learn the base ideas, then they can go on to other science ideas.

Tom was asked to draw two concept maps, one prior to the classroom observations and one after the classroom observations. His first drawing has a large Physical Science area that encompasses the other science areas he taught as if it is the base he talks about. The first diagram, Figure 9, appears to be inclusive of other science areas. This diagram is not really a concept map, but rather an illustration of his thinking about the content he teaches.

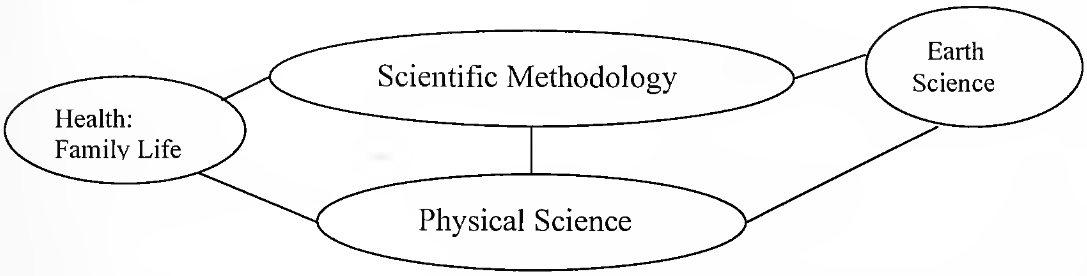
Figure 9: Tom: SMS Diagram – Prior to Classroom Observations



His second diagram, Figure 10, is quite different from the first. This drawing is more like a concept map, with separate circles connected by lines. The first drawing could be much more indicative of a connected view of science than his second diagram. It is hard to determine if these circles are connected or have boundaries for the discipline areas. When asked what the lines are between the bubbles he talks about the separateness of ideas and a connection among all sciences, but not his separate circles.

I am referring to the independence between all sciences.... I mean there is a difference even though there is a difference in their tangents. There is a real connection that is shared between all the aspects of science.

Figure 10: Tom: SMS Diagram - After Classroom Observations



His second diagram is a little more specific than his first, but there is still not much detail about the topic areas. The differences in the second drawing are graphically different, and include the topics of scientific methodology, health and family life. The biggest difference is that he mentions the scientific method. He describes this addition.

Scientific method. Obviously, scientific method is first before you can jump off... You have got to understand the methodology. You know how to approach a problem and then I think there are some overlapping skills in physical science and then start taking it off into the other areas of science. They have a base then.

He goes on to describe the importance of the scientific method and how it is used in classes. It is an area he finds important in his teaching.

Well, you use the scientific method in all science. Science just has to use the scientific method period, in all areas. You need to have that basics skill down before you can move on. Someone has to know and learn how to think about things in a logical scientific fashion. Not everyone thinks in those terms. It is a skill that has to be addressed with a lot of kids. It is why I do the science fair type of activity. I constantly say this is how you approach a problem.

He believes that the scientific process is the core to solving problems in science. Students have to be able to use the scientific process to be able to solve problems. He believes his training in science helps him solve problems and that any person with a science background will solve problems in a different way from people who do not have that type of training.

You know, in solving problems there is scientific approach. But when you get down to brass tacks it is really just a logical approach to solving problems. So yes and no. Does that make sense? I think the way scientists tend to solve or using the scientific method we all should know but we all don't. There is a logical way to solve things and yeah there is a way to thinking scientifically that can spread across our lives. I think we accuse scientists of thinking differently. They don't think differently; they think logically. We sometimes as humans, we have the tendency to go on emotion.

He thinks middle schools students can develop the science skills for making observations, analyzing and predicting events. He does put one limitation on their ability to learn and apply his ideas; only exemplary students who will take these ideas out of the classroom.

I think it is possible to give kids skills to understand making observations, analyzing and predicting but I think in eighth grade to be honest with you it is an exemplary kid who can take it out and apply it to their life and say wow this is how I think about anything. I think eventually they come to that but not all in my science class. By the time they come to eighth grade, their thought processes are pretty well intact, and hopefully as you teach them more.

Another method for checking to see if Tom's thinking changed during the study is through his responses to the survey questions. When he was asked the same questions from the original survey, his responses are not consistent between the two times they were asked. He selected the response for the first question on the survey*: It is best for students to learn science in a real world context, such as reproducing phenomenon in experiment so they see they science concept represented.*

When asked this same question in the second interview he described the need for the content to have a place from which to start or a base.

You've got to have that base. I think part of the challenge is to take that base and say, now look where you can go with this. Look how it applies over here in biology, look how in geology it all ties in. I think once you have established that base, whether you establish by tying it in initially or you start by teaching the

base. I know when I learned it, it was easier for me to develop a base that I could carry with me to different areas.

He didn't want to answer the questions directly and he responded with these explanations. The base for Tom seems to mean an understanding of an area of science before going on to another area.

Well the important lesson I got out of biology is that it carries over and it is how things are classified. When you talk about so many different things. How do you organize your... To finally have a light go on in biology and say now I finally understand why they have these classifications. Before you can teach DNA you have to understand what is a molecule. So you have to have a base of science before you can get into the more abstract science.

This response indicates that he thinks there is a sequence to learning in science: students have to learn the base first before they can move into more abstract topics.

When the second survey question was first asked, he selected the response: *Students should focus on enough specific areas of science long enough to learn about the topic and its connections to the properties of science that are related.* When asked the same question again, he talked about his own thinking about science, how the high school teachers are considering incorporating more sciences into one year of science. He discussed its validity.

You know I remember when I had to fill it out [the first survey] and my thinking has changed a little. I was talking with the high school teachers about why they were changing from the biology and earth science, chemistry, and physics format. It is because of all the new discoveries in the genetics and things like that are going so fast. Yea, I do think you have to prepare kids and make the connections...I am beginning to see why they [high school teachers] would want to change what, or the sequence of what they are teaching because of the way science is changing. You have to have the base, but you have to be able to make it relevant as to where it is going.

He continues to reflect on and discuss the change being suggested in science in his districts but come back to the idea of a base. This indicates that his thinking is unstable about the whether science is connected.

I think you have to have the earth science, biology – chemistry - physics sequence and that is good to hear. Things are changing so fast that it is hard to keep up. That isn't wrong and maybe it had worked. But maybe what you do is look at the course offerings and say we teach the base and then we go to more complex things in the second half of the year. Maybe it is a combination of base facts and knowledge before you can jump off into the some of the more abstract things .

While he talks about his thinking about the connections in science, he relates it to the content he is teaching. In this discussion he talks about the benefits in his content areas, and he reverses some of his earlier comments.

What is nice about chemistry too is that it overlaps so heavily with all areas. So from now on when we go onto geology, so you can talk about how crystals and formation of .. so they have the background so you can get into things a little deeper. Like weather, you are talking about the composition of the atmosphere.... No, no, no that is what is great about it physical science to say now you can see how it applies it applies over here in earth science. And two or three areas or two or three other areas it builds on stuff. Again that is why I like physical science because it does seems to spill over in all sciences more than any other them. Maybe it is the way I think (laugh).

Tom indicates that he can talk about the connections in science and understands where connections can happen in his curriculum. But this conflicts with his idea about when it should happen and his notion of a base has to be learned first before other abstract ideas can be learned. What is not clear is whether he thinks connections within science are complex or not. What is clear is that his SMS is not stable, but tends to assume that science is not connected except when he thinks about what other teachers are doing.

Summary for Tom

Tom's beliefs about science as a discipline seem to be in flux or in conflict. He isn't able to consistently envision whether science is a connected discipline or not. His views seem to change depending on whether he is talking about the big picture, his classroom, or what other teachers are doing in his district. He believes that there is a base

of science that should be learned first before students can learn more abstract ideas. He didn't give an example of this notion, but it implies that he thinks there is a coherency of science. He believes that the ideas of science are linked in a way that if you learn one idea, then other ideas can also be learned. It also implies that there is sequence in science. If you do not follow the sequence, then students will not be able to learn later ideas.

His ideas about science affect how he teaches science. The effectiveness of how he implements curriculum materials is very much influenced by his beliefs. Tom's beliefs have a strong influence on his classroom curriculum; thus they affect the curriculum at the first levels of the TIMSS tripartite model of curriculum.

Tom's ideas about students and how to teach science are also strong influences on what and how he teaches for science. These beliefs strongly influence his teaching in the areas of coherence. It is hard to determine whether they impede effective science instruction. If effective science instruction includes connections [reference to science standards] in science, then yes, his beliefs impede effective science instruction. His notion of a base in science also prevents him from teaching certain topics before others.

For Tom, there is relationship between his beliefs and knowledge regarding the coherence and connectedness of science concepts and his classroom practice. He appears not to recognize connectedness in science and he does not teach that way. He appears to be considering the idea there is a connection in science, but he does not demonstrate this in his classroom. His unstable ideas do not show up in his teaching as he stays close to his content without making connections to other areas. Given this analysis, Tom is primarily a Type I teacher: singularly content focused.

Helen: Willow Middle School

Introduction

Helen is a sixth grade teacher at the Willow Middle School located in a fast growing suburban community.

Academic and Professional Profile

Helen didn't initially plan to be a teacher. Her first career interest was in computer science, but after two years of college computer science, she switched to medical technology and finished with a degree in the medical field. After graduating from college, she worked for a few years as a surgical technologist. She enjoyed the job, but began to think the job was a potential dead end for her, so she returned to college and earned a bachelors degree in biology. With a biology degree, she began to think she might enjoy teaching. She did some substituting in the local schools and found she liked working with middle school students. She became certified to teach in a fifth year certification program at a local state university. With this science background and experience working in science, she feels well prepared to teach middle school science.

She is beginning to learn about the various options for on-going professional training as a teacher. She has attended several conferences to learn more about teaching and teaching science. She is active with her learning and knows, as a new teacher that her learning should help her to do her job more effectively.

Class-Specific Perceptions and Concerns

Helen expresses a wide range of concerns about teaching students as well as her beliefs about what she should be doing and how her students learn. She is fairly new to teaching. She is learning many things about teaching students, the other teachers and her school. With all of these issues, she still has a very positive attitude about teaching.

Her classroom is small and filled with student desks, so there is little room to move around when the students are at their desks. She has carpet on the floor in this cramped room making it challenging for her to do science activities with materials. There is a storage area for classroom materials which is fortunate because of the lack of space in the classroom. Three of the days I visited her classroom, she had no heat in her room and the students had to wear their coats.

The science curriculum committee is revising the sixth grade curriculum. Textbooks have been purchased for teachers to pilot to determine if the school should purchase them. The teachers have some flexibility in using other instructional materials

so that they can help students to meet the state's standards. If the textbook doesn't cover the content required in the state standards, then the teachers can use other materials.

> *This year I am going to pilot a Prentice Hall book.... Those books were chosen by the way they presented material and for the things they offer help us meet the Learning Results. I will use that as my guidelines, but I'm able to implement any activity that I choose that I think will help my children to meet the Learning Results or goals that I want them to achieve in science.*

Helen has a strong science background and a challenge for her is balancing between teaching sixth graders and teaching the science she enjoys. Because of the implementation of the state standards, she has looked at her teaching differently.

> *They [standards] have affected my teaching of science very much. Because we are expected to teach to the standards.... We have to meet the standards in our teaching. So I think it affects my science in the way in which it tells me what I have to teach that year. It doesn't tell me how to teach it, but it does tell me what needs to be taught.... I think it is good to have something to go by in schools so they don't have overlap so everyone gets everything. So that is how it dictates what it is I have to teach.*

She seems to understand that there can be coherency in a student science program. She describes this as not duplicating topics or selecting and teaching topics in science that conceptually build on each other. She does think about her curriculum as promoting a sequential learning process. This is important as the students that come to her school came from three different elementary schools and three very dissimilar science program experiences. This different learning experience of her students in the K-5 grades adds to her frustration about teaching science at the middle school level because of the lack of coherence and sequence of science at the K-5 levels.

> *We just have a list of what things we have to cover in each grade. Usually they are not related. One does not really build on the other. I had a question last year as I had energy and had Newton's laws and I did some stuff on volcanoes. When I did volcanoes a lot of kids had already had it, so I rearranged it. Like half of my class as I had 70 students they had three different science classes. Maybe one third had prior experience learning about volcanoes but they were not all in depth*

and the same perspective as I incorporated forces and motion and that is what we did. We did a few other things like talk about friction and how to build up pressure in the plates. So we have been trying really hard not to have overlaps in our curriculum.

She can describe her program in detail. When prompted to make a visual drawing displaying her curriculum as a part of the SMS task, she drew a series of pictures with arrows connecting one to the other to illustrate how her year progresses. It was a storyboard of the content she taught during the year. The drawing and description represents her thinking about the content sequence but also the importance of content order. It indicates knowledge about science, how ideas are related to each other and connected, but also how science can be coherent when certain ideas are connected.

So at the beginning of the year we talk about the scientific method and we have the kids ask questions and observing so I have a little question mark. Then I draw a little person with a microscope on the table. We do some little experiments. And the steam on the head is the student trying to think about the connections and then write up a report for the scientific method.... Then I have a picture of a little cell. Then a picture of city because to help the kids understand how the cells work together like a city it relates to a city and different things in the city. We really get the idea of the power plant and the energy, power and control it kind of helps them make that. The next thing is two little beakers that is show how they learn about osmosis and how things change in different environments.... I have some little reports. That is mostly because I want them to be able to communicate what they learned. It doesn't necessarily represent a task but an assessment.... Then I have a sun and a plant vs. a person. That is to represent photosynthesis and respiration and how plants get food and how people get food.... I have them do an activity with poker chips to show them how the chemistry got involved. Different poker chips represent different carbon hydrogen and oxygen molecules and I give them a certain number and they go thorough the activity and go through the .. I forget the word.... The something in the products... the reactant in the products.... By the end of the activity they get how the plants and people work together, how the product for one is the food for the other.... Then we go to mitosis, mostly

mitosis, I didn't do mitosis last time but I might do it this time. I really want them to understand cells and how they reproduce. And then I have some bird silhouettes because we are supposed to do Darwin's finches and natural selection and then I have dinosaur things drawn because we do fossils and that is it.

Piloting the curriculum this year with sixth graders was more challenging than she had anticipated. She found large differences between her past seventh grade students and her current sixth grade students' thinking and ability. She plans on making some revisions for next year.

It was a bigger difference than I thought. It took me a lot longer to teach cells to sixth graders. It probably took twice as long. Because I taught a cell unit in the seventh grade in I think three weeks and they could do osmosis, the diffusion. They could tell the organelles and the relationships.

She uses the Internet, CD ROMs and other technologies when she can to illustrate science concepts. She likes to use technology in the classroom, but feels limited by the access to the computer lab or to computers by students. She has also had few resources for purchasing new software and equipment. Even if she had lots of hands-on materials for her students, the small moveable desks and rug in the classroom are not conducive to activities. She wants to do activities because she believes that is the best way to teach middle schools students, but she doesn't always have the correct materials.

I think they learn by doing. Because it doesn't matter how long I stand up and talk to them and repeat things or have them repeat things back to me. If they do it at least they will remember doing it. They may not remember the names, but they remember holding it or seeing it and could probably describe it. They have even told me that. They like it better when they do labs. They understand it better.

She had to work around some classroom limitations. During one series of lessons I observed, she was doing an activity on osmosis. She had to borrow another teacher's classroom which was larger, had lab tables, and no rug in order to do the activities more safely. This worked out pretty well, but students had to spend time moving back and forth from the classroom. The lab room was not available during one day in this sequence of activities, so she had to do something else.

She appears to work hard to help her students learn the processes of science and observe the world around them. She states that she believes that helping her students think and ask questions are key to their learning science.

> *If they know how to think about how to do it themselves they can do anything. So that is what I want them to learn. I mean yes they have to get the knowledge in to be able to know laws and know what things are called. But I really think they need to formulate questions and explore by themselves and find answers.... If you take away the environment then it may react in a different way. Those are the kinds of things I want my students to understand or learn. I don't know how to put names on that.*

She does talk about using the science method as a way to help students learn how to think. This idea of students thinking for themselves seems to be an important goal for her as a science teacher.

> *I think the most important aspect for them to learn is to look at things and ask questions about things and learn how to find answers to their questions. I want students to look at something and wonder what makes that blue or green and then know how to make up some question or statement and know how to go about finding the answer to that. It is more of a process of thinking.*

Classroom Observations

This section describes recorded data. This includes the observation instrument, instructional materials, teacher and student handouts, and researcher notes from the observations. A part of a unit in life science unit on cells was observed. The unit began a month earlier than the observations and it continued a little longer. The part of the unit the researcher observed was on cells. The classroom had student display models of animal and plant cells; other student work from the unit was posted around the classroom.

There were two outside factors that influenced the content recorded in the observation for Helen. First, there were three visits by a teacher from a neighboring city water district to teach classes. She normally visited the classroom once a month, but because of interruptions of the school schedule, she was observed and included as a part of the science content for Helen. She taught lessons that included information about a

nearby lake, as it is the water supply for a city about 20 miles away. Two of her lessons were included in the classroom observations because they do represent the reality of the coherency of the science content taught in the classroom. With the inclusion of these lessons, additional observations were also made for Helen so that the minimum of hours was met excluding the visiting teacher.

The second factor that affected the science content and coherency of the observation period of about three weeks was four snow days, two conference days and several days of teacher illness. This caused the observations to be spread out over three months rather than a month, and tended to make the content coherence in the classroom seem fragmented. Helen made several efforts to connect the lessons between the breaks in the schedule through reviewing and returning to activities when the students had difficulty remembering the principal ideas. Even with these intervening factors, the science content in the classroom observations did indicate a pattern. The general pattern would not have been different if the observations were uninterrupted.

The content in the classroom observations are displayed in Table 11. It is apparent that Helen tended to stay focused within the curriculum topic while making connections to some other science areas. The number of connections is greater than those of some of the teachers, and less of other teachers in the study. This pattern for Helen is consistent, including the visiting teacher dealing with earth science topics. The recorded content without the visiting teacher would have shown a slightly lower number of connections.

Table 11: Helen - Science Content

	Number of records	Records in areas within those Benchmarks
Nature of Science, common themes, and habits of mind	33	5 of 13
Other stated content curricular Benchmarks	108	3 of 7
Non-stated curricular Benchmarks	44	6 of 25

She did stay with her content focus, but made an effort to connect to the Nature of Science, Common Themes, and Habits of Mind and the non-stated curriculum content.

The science content connections occurred when the visiting teacher was in the classroom and when Helen was conducting experiments or activities and not in the teacher-led discussions. When looking at the non-stated curricular connections the researcher noted Helen made 6 out of the 25 possible connections.

The instructional content presented by Helen was narrowly focused on aspects of cells and some on the function of parts of the cells. For the water district lessons, they were mostly focused on hydrology. No instructional materials or teacher-led connections were made to science areas such as DNA and inherited characteristics, disease, biological evolution or energy flow in ecosystems as identified as possible grade level 6-8 connections in the Atlas of Science Literacy (AAAS, Project 2061, 2001). Helen did discuss the chemical reactions in the context of osmosis of the cells. The connections made were to areas less closely related to the unit topic. The emphasis was on the functions of the parts of the cell and how those parts worked together. Links to other areas did not seem a part of Helen's intended curriculum.

> *But, like in my unit, yes, I had them try to memorize parts of the cell but I want them to memorize the parts of the cell to see how they worked together.*

In general, Helen stayed focused on the curriculum topic of cells. She wanted her students to learn about cells and their function. She did make some connections, but the intentionality of those connections is unclear from the classroom observations. The intentionality of her teaching including connecting to other science areas was also explored.

Self-Described Subject Matter Structure

This section describes Helen's stated beliefs about her SMS and specifically her beliefs about the coherence and connections within science. Both interviews, two repeated survey questions, and the Structure Matter Structure task were used as sources of data to document her beliefs.

During one interview she described the essence of the science she teaches. Helen emphasized the process of discovering how things work, what they are and how they interact as science rather than the factual knowledge base of science.

I think science is discovering things around you. Discovering how things work, what they are, and what makes things up, and how they interact. That's what my view of science is. I think science is just the study of learning that. Scientists have just given meanings to all these things when they found out about them.

This description indicates that thinking in a scientific way is important. Helen goes on to describe her beliefs that science as a connected discipline

I think it will benefit them more, if you could connect the sciences.... Where I use the chemistry in photosynthesis they understand it a lot better. They really get when they have to do an activity when they are going through the photosynthesis and respiration reaction.

Also she described that a goal of hers is to help students understand the connection between science and mathematics. This area of connection was not observed.

I would like to help them see the direct connection between math and science. ... they would have their data in there and then it would produce the graph and then we could do formula and then they could see how. I think that would be the most concrete experience I could give them to understand the connection between math and science.

She added to her description her ideas about the connectedness of science when she described how the science discipline lines we understand may not be important for middle school students. The lines of distinction she refers to are the lines creating the separate fields of science such as biology, chemistry and physics. She doesn't consider it important for students to know whether they are studying physics, chemistry, or biology at any one time. When asked about the importance of discipline names such as biology, she responded in a general way about what might be best for middle school students.

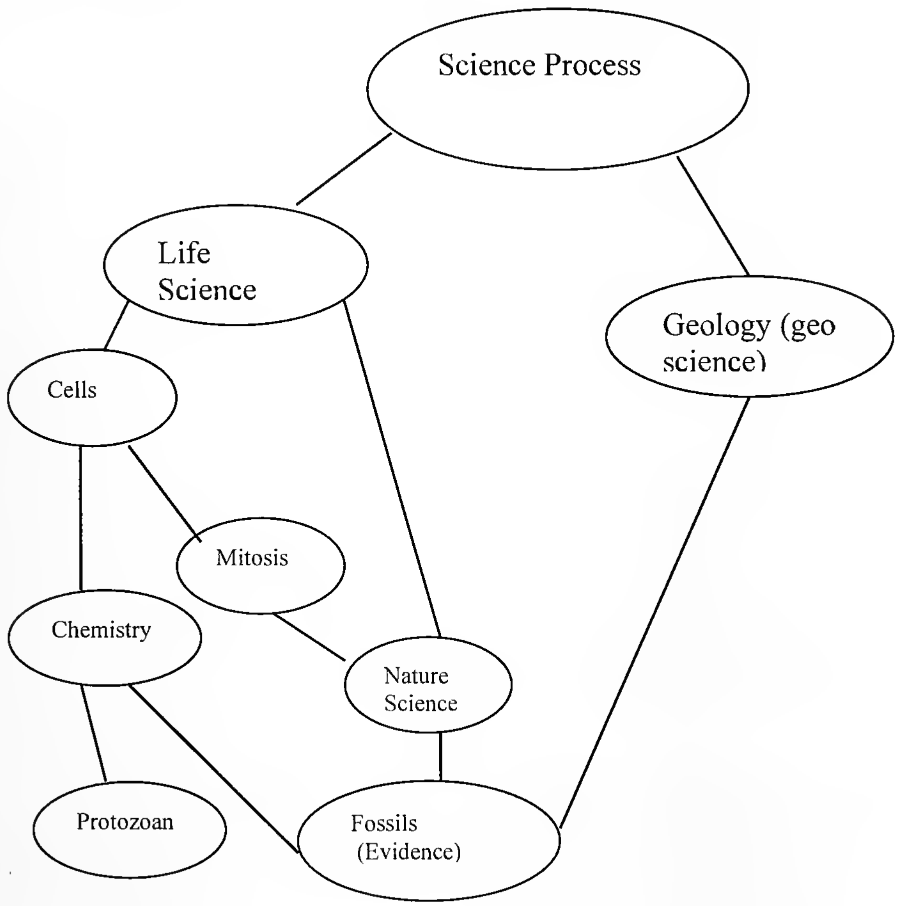
I am not sure whether they need to know that in middle school. I think they just need to know that this happens.

Her response to the Subject Matter Structure task occurred in two parts. The first was a sequential diagram much like a storyboard of what she teaches throughout the year. Then, on request, she drew a concept map. In the storyboard, it was more difficult to interpret any connections as it was sequential and reduced the possibility of her noting links outside of her sequence. It did illustrate that she has a plan for a yearly content

sequence. Her concept map shows her major curricular units and the importance of the units. There are "origin" topics leading to other subtopics. There is little detail in her concept map. She stated she had never before drawn a concept map of her curriculum.

The flow of science concepts in the storyboard was similar to this concept map. They both had a direction and a conceptual development beginning with an emphasis on the processes of science, then identifying the large topical areas, then moving to cells, organs, then cloning and finally fossils as evidence of change.

Figure 11: Helen: SMS Diagram - After Classroom Observations



The largest circle in the diagram is the scientific process. She repeatedly talks about the importance of her students being able to think scientifically. This is important to her as a science teacher as it show up in her SMS diagram. She also articulated this belief about science in her first and second interview.

I put this as scientific process only because you use this throughout. Whenever you are studying science, I mean you always have some kind of question that you are going to explore and you try things out, you find some facts, and that is just what you do.

If Helen makes connections within science, it is with the scientific processes. This means several things to her from questioning, observing and exploring ideas.

We use it with all the different experiments or they have questions we explore. If they can't figure out exactly what I mean, I come up with different things for them to explore. I would like to do more specific experiments to use it even more, but I don't have the resource to do that right now.

When asked about the specific link in her SMS drawing, the lines between topics, and whether she felt she made them explicit in her classroom. She stated that she could make connections, but wasn't sure she actually makes them in class. Her conflict seems to be between her ability to use her science knowledge and make connections, and her lack of knowledge and experience in the classroom to make them explicit for students. She sees the connections herself, but appears to have some difficulty making them for her students.

I don't know if I have necessarily done that. I think about it that way in my head. I recognize that connection is my head. So if someone asks me to do it, I don't know how to do but it makes sense to me. So it is oh, I never thought about breaking it down. Sometimes to me so many things are connected I don't really know how to separate them.... I could connect every single one of these if I really wanted to and I could give you a reason how.

What is not clear is whether she believes those connections should occur in her classroom. She seemed to be still learning what science is appropriate for her level students, which might be a barrier to making connections in science.

In the second interview, two questions were taken from the original survey. One choice was that science is not connected and the other was that science is connected. The reason for repeating the questions was to look for the stability of Helen's thinking over the period of the study and whether her thinking had been influenced by her participation.

In the first survey, Helen selected a response that characterized the best way for student to learn science as being congruent. *It is best for students to learn science in a real world context, such as reproducing phenomenon in experiment so they see the science concept represented.* In her second attempt with this same question, she was cautious and took her time in her selection. She ultimately selected the same response and went on to discuss her selection.

> *I probably wouldn't pick the separate components of science. I probably won't. Just because it says separate components. To me that is like if I just told them this is the cell and memorize the parts and go on to other things.*

Her original response to the second survey question was the one that characterized science as more connected; *Learn about science in an integrated fashion to gain insights into the breadth of science and other fields and not focus too long on particular areas of science.* When she was asked this question again, she also took her time and appeared cautious. She described her response in the context of what she was able to do in her teaching of science, rather than what she would like to do. She responded from a perspective of the reality of her current situation.

> *These are hard questions. It really depends on how you look at it. It would be easy to make a choice that you really didn't want if you didn't take the time. So, because the teacher illustrates connection, I do not like the term. Now sometimes I have to do that because I don't have the resources. I would love to have Internet and be able to have a classroom and use computers so I could teach them like in computer room. You could bring in all sorts of cool things that way.*

The other aspect of science she describes in her teaching of science is the coherence of her curriculum and science. She believes that the way her curriculum is designed represents a thoughtful sequence that will build conceptual learning.

> *Well it [the curriculum] is all linked by the cell, really. I mean it is kind of stretching it with the cell. Well you are not really stretching it with the finches and fossils because they have to do with heredity and differentiation, and we learn about mitosis and we talked about the abnormalities that can happen when things don't go right.*

Helen has a strong background in science. She talked about how that background both affects how she approaches teaching science, and how she may look at the world differently from people who don't have a science background.

I think people who are in science pay attention to details. You are a lot more aware of what is going on around you. You maybe even anticipate things.... When I am with people who are not science people, I usually notice things that they don't. I usually anticipate things that they don't.

She goes on to make a comparison between herself, and her colleagues in her school and even other science teachers in her district. She believes that her background positively affects her teaching of science, but is concerned about the lack of science background of her colleagues and how it affects their teaching of science.

It seems to me by just talking with people that people who really don't have a science but just an education background seem to still be concerned about kids knowing the facts in science. They want the book so that a kid has the book to read the information. It is like the book is the crutch. Where, for me there is so much in science that they are not going to remember all of it. And you are only going to remember the things that you are working at and you can always look up the ones you forget. I don't think non-science people really do that. After a conference I just went to, I am not sure some other science people do that either. To me when I talk with other teachers, no one else in sixth grade has a science background, and I keep trying to communicate to them that the students need to know about the process of science and we need to get them to understand the cause and effect, the variables that are really more important than memorizing this term and that.

This year teaching sixth grade has been a learning experience for Helen. She learned that sixth grade students are quite different from seventh grade students and that she may need to make some modifications from what she taught this year.

I am not going to do it in the same way. I did it that way because I was piloting that book and we wanted to see if the book was going to work.... It has taken me too long on this one topic, and so I am going to do this a different way. We are

still going to talk about cells and the environment. I am going to look at it in a bigger way. We looked at them in a microscopic way.

Summary for Helen

Helen enjoys her students and teaching. This study was attempting to see if she believed that science, as a discipline, is a connected and coherent field of study, or if it is comprised of separate areas of study. Her beliefs were consistent over the period of the study concerning the importance of the processes and the nature of science. Her response, in the original survey, interview statements, and subject matter task diagram were consistent. She clarified her views that science has connections and that it is helpful for students to see those connections. When she thought about what she was teaching and what other teachers were teaching, and her own beliefs, she seemed to separate the ideal situation, a connected science, and reality of what is actually taught in classroom.

Her beliefs about the coherence of science, and about helping students to learn science through building ideas on one another and connecting them to related ideas was consistent throughout the study. She did though, in the final interview, begin to question her ability to do this within the constraints of time, school personalities, the standards and selected curriculum materials. This exemplifies the complexity of factors in the classroom and teaching entering into her beliefs about teaching science.

Helen's teaching was focused and intended to help students learn concepts. She occasionally departed from the curriculum to help her students learn ideas. She adapted her instruction for her students according to what she believed were important for them to learn. Her knowledge and beliefs did affect the effectiveness of curriculum materials at the first levels of the TIMSS tripartite model of curriculum in that she made changes in the curriculum according to what she believed was important. In most cases she made the changes because of the standards, but also when she felt her students did not understand the concept. The curriculum was only the guide, and was not exactly followed.

Helen has strong beliefs about science and how it should be taught. She gave as an example of what she believed was exemplary teaching a college chemistry course. It was constructivist oriented and she was able to make decisions about her learning. She has not yet been able to teach that way herself. Her beliefs about the coherence and

connections of science have not translated into her teaching. She has yet to marry the two aspects of teaching in a way that helps her continue to develop effective science instruction. Her lack of experience in teaching is a disadvantage, but her enthusiasm for teaching will help her keep improving.

The relationship, if any, between Helen's beliefs and knowledge regarding the coherence and connectedness of science concepts and her classroom practice is fairly clear. Her practice in the classroom does not show the same level of consistency in making connections as she discusses in her interviews. The levels of explicit connections made in her classroom were not consistent as compared to the level of acknowledgement given in the other data sources. Her ability to talk about the reality of teaching and the ideal for teaching indicates that she knows there can be another way to teach science. Improving her physical classroom space would also help.

Helen is a hard working teacher who has been teaching for only four years. She acknowledges that she is new at teaching and is learning about what works best for students. She is open to learning more, even while being a little frustrated with the lack of curricular coherence across grade levels and lack of instructional materials. Because she is hard working, she will keep trying to make her science classroom experiences better for her students. Given this analysis, Helen is primarily a Type III teacher: unfocused on the stated content.

Chapter V: Analysis of the Teachers as a Group

Introduction

This chapter discusses aggregate results based on the information and materials from all six teachers. This chapter examines the similarities and differences among the six teachers and whether there are specific characteristics of, or prerequisites for, teachers who teach science in a connected and coherent fashion. Though the conclusions made from six teachers may not apply to the total population of middle school teachers, the findings will provide patterns or indicators of teachers, allowing for hypotheses which can be further explored with a larger sample of teachers. The sources of information for this analysis are the same as previously used: the survey, two interviews, classroom observations, researcher notes, and instructional materials. This aggregate analysis is divided into four sections: the Survey, Pre-Observation Interviews, Classroom Observations, and Post-Observation Interview.

The first section discusses results from the original selection survey. This analysis assists in determining whether the knowledge and beliefs of the study teachers as a group are similar or different from the total Maine middle school teacher population.

The second section discusses the study teachers' impressions, as a group about teaching science, what is science, how they make choices about what science to teach, how they stay current in science, their curriculum choices, and their perceptions about teaching in their school. This information was gathered from the first interview prior to the classroom observation. Similarities and differences in their perceptions and beliefs are noted when they occur.

The third section, a summary of the Classroom Observation results for the teachers as a group, examines the observation data, instructional materials, student materials and researcher's notes to provide a picture of the study teachers' practice as it relates to their subject matter beliefs about science. This analysis begins to allow a formulation of patterns of classroom practice illustrate connected and coherent science teaching.

The fourth section discusses the post-observation interviews for the study teachers. This includes a summary of the SMS concept map diagrams, and how the teachers think about the science they teach. This section assists in refining the picture of the study teachers' beliefs about science and the influences those beliefs have on their teaching of science.

Final conclusions about the study teachers' beliefs as they relate to their practice and the implications of these conclusions for teacher education, professional development and further research are presented in Chapter VI.

Survey

The analysis of the study teachers as compared to the total population response on the survey showed similarities and differences between the study teachers and the general population of Maine middle school science teachers regarding the definition and nature of science, and whether they believe science is a connected discipline. Because of the limited focus of this study on the beliefs and practice of the teachers, only a preliminary analysis of the eight core survey questions targeted to collect information about the teachers' beliefs and knowledge of science was done rather than a complete analysis of all sections of the survey.

The general population of middle school science teachers had a wide range of responses to a question asking them to choose a definition of science. Less than half or 39% of all the respondents in the general population agreed with the study teachers about the definition of science. The prompt in the survey was:

Defining science is difficult because science is complex and does many things. But science mainly is:

a. A study of fields such as biology, chemistry and physics
b. A body of knowledge such as principles, laws and theories, which explain the world around us.
c. Exploring the unknown and discovering new things about our world and universe and how they work.
d. Carrying out experiments to solve problem of interest about the world around us.
e. Inventing or designing things (for example, artificial hearts, computers, space vehicles)

f. *Finding and using knowledge to make this world a better place to live.*
g. *An organization of people (called scientists) who have ideas and techniques for discovering knowledge.*

The study teachers selected c. *Exploring the unknown and discovering new things about our world and universe and how they work.* Sixty-one percent of the general population of middle school science teachers selected one of the other responses to this question. The general population's responses ranged across the possible answers (Table 12). In earlier studies using this VOST question there were minor differences by gender. Females were more likely to select response c. than males (Bottom. & Brown, 1998; Zoller, Donn, Wild, & Beckett, 1991). Science teachers with a stronger science orientation also selected response c. (Zoller, et. al., 1991). There was a difference in results in this study as compared to responses by college age students (Ryan & Aikenhead, 1992). In this study, there are three females and three males. All have a strong science orientation.

Table 12: Response Rates and Percentages for Survey Question # 1

Response	a.	b.	c.	d.	e.	NA	Total
N	4	33	43	6	21	5	112
% of Total	3%	30%	39%	5%	19%	4%	100%

The difference in the responses to the first question was higher between the identified teachers and the larger population in this application of the survey, but no strong factors exist to help explain the difference. Further research would be necessary to determine the importance of the difference.

For the remaining seven questions on the survey, there was stronger agreement between the study teachers and the general Maine Middle School science teacher population. These questions asked about the teachers' beliefs about whether science as a discipline is connected and coherent. For these seven questions, the agreement was 88%, 56%, 85%, 67%, 75%, 75%, 55% between the whole population and the study teachers. Two of the questions had a lower agreement rate than the other questions; question 3 at 56% and question 8 at 55%.

Scientific observations made by competent scientists will usually be different if scientists believe different theories. Your position basically is:

a. *Yes, because scientists will experiment in different ways and will notice different things.*
b. *Yes, because scientists think differently and this will alter their observations.*
c. *Scientific observations will not differ very much even though scientists believe different theories. If scientists are indeed competent their observations will be similar.*
d. *No, because observations are as exact as possible. This is how science has been able to advance.*
e. *No, observations are exactly what we see and nothing more, they are the facts.*

The study teachers selected c and d. These two responses indicate of a more current view of science. One could interpret this to mean that the general population has a large portion of teachers who think of science in a more traditional manner.

The other question had a slightly lower agreement level.

Science is an ever-changing discipline. Scientists are learning more and more about the world. This causes them to often focus on narrower and narrower aspects of science. This may impact students' science learning. Your position basically is:

Science has major core topic area and student should:

a. *Learn the discipline of science such as biology, chemistry and physics over a period of years to be able to learn about new discoveries.*
b. *Be exposed to a variety of new science learnings in multiple areas of science, but focus on the areas of science such as biology, chemistry and physics.*

Science is integrated and has connections within the discipline.

c. *Students should focus on an aspect of science while the teacher illustrates connections to other science areas such as biology, chemistry and physics not studied at that time.*
d. *Students should focus on specific areas of science long enough to learn about the topics and its connections to the properties of science that are related.*
e. *Learn about science in an integrated fashion to gain insight into the breadth of science and their fields and not focus too long on particular areas of science.*

This question was focused on the teachers' beliefs about the extent to which science is connected. All of study teachers selected one of the three choices in the second part of the question: c, d, or e. Approximately 55% of the general population selected one of the three choices in the second part of the question and 45% did not. The variation is between

the two groups of teachers is only significant for this study in that the general population selected a range of choices indicating that there is no consistent belief about science being connected, whereas the study teachers were in agreement.

From the analysis of these questions on the survey, the general Maine middle school science teacher population is not in agreement about how to define science. The teachers in the study differ slightly on whether they believe science is connected discipline. The two groups also have in common a range of responses on other questions about science being coherent and the nature of science. This has been found in other applications of the VOSTS (Bottom & Brown, 1998). This analysis adds background information about the study teachers and their beliefs as a group.

A complete statistical analysis of this data has not been conducted, as the survey instrument was used only to identify a set teachers for the study with beliefs about science being connected and coherent, and not to compare the differences between them and the whole population of middle school teachers in Maine. The significance of these differences needs to be explored further, and areas of further study need to be identified.

Pre-observation Interview

Background data was collected. Some general education information about the group shows all six teachers had at least two years of a science major in college before changing to education and five out of six had a degree in science prior to obtaining a teaching certificate. In their use of instructional materials, all had a text and/or commercial instructional materials as a part of their curriculum, but only three out of six use the text. Those who did use a text, used it as a guide for their content sequence. None of the teachers used their text regularly. All of the teachers created, selected, adapted and organized their own instructional materials instead of, or to supplemented textbook materials.

When asked in the interview, several key areas about the teachers' beliefs about science seemed important. The first area is how they define science. All of the teachers responded in a similar fashion talking about science as an activity rather than as a body of knowledge. Some sample quotes representative of the group of teachers are:

Tom: "I think science is discovering things around you. Discovering how things work, what they are, and what makes things up, and how they interact. That's what my view of science is. I think science is just the study of learning that."

Patricia: "I believe that science is the way the world works around us, but that it also is how we choose to learn about that world around us.

Robert: "...the way the world works around us, their bodies and all the things we study in science. Science is also a process that we do things, or logical ways or the scientific method.

These statements are in general agreement with all of the study teachers' survey response regarding the definition of science.The study teachers also talked about science as a connected discipline, and showed some concern for how large a discipline it is which leads to difficulties in teaching science. Knowledge and beliefs about science concepts and how they are connected are not consistent for all of the teachers. Samples of their thoughts show the similarities and differences in how they think about the connections in science and what this might mean for teaching.

Robert: "It has always amazed me that the higher up in science you go, that we always see science and art as separate things, and the higher up the scale on both of them you realize how connected they are."

Helen: "I think science is so huge that there is none. There might be a culture around technology, or a culture around chemistry, but not around science. Because there are so many different kinds of sciences. Like environmental science is very very different than say astrophysics."

Celeste: "I think that, maybe it doesn't have to be every year you do every single thing, because it would be too watered down, but I think throughout the years there should be a conscious effort to teach physical and life sciences and how they interconnect."

These comments from this interview are not in complete agreement with how they responded on the survey.

The final area of interest about their beliefs was their explanation of whether their backgrounds in science affected their beliefs about science as a discipline. They stated

that they believed their knowledge of science leads to a different way of thinking about the world. The following quotes are examples of their thoughts:

> *Patricia: "I think people who are into science tend to think differently about things. Is that what you mean? That they tend to be more analytical, tend to want to see the whole picture."*
>
> *Robert: "I think people who are in science pay attention to details. You are a lot more aware of what is going on around you. You maybe even anticipate things."*

The influence of the study teachers' background is difficult to determine for their statements but they do believe that knowing science causes people to think differently from people who do not. This is supported by research, but, what needs to be investigated is how much science is needed to think scientifically.

This interview added further definition to the group's agreement about science, but showed slightly divergent thoughts about the connectedness of science. They also believe that people with a science background think about science and the world in a different way than people who do not have a science background.

Classroom Observations

An analysis of the observation data for the group of teachers shows some general patterns. These patterns are evident in the science content is taught and whether it is coherent and connected. Looking at the aggregate number of science topics presented during all of the classroom observations, the researcher noted that the study teachers covered many of the topics listed in the Project 2061 Benchmarks during the one or two units observed.

The topics that the teachers stated they were intending to teach were clustered in three major areas. The two most frequent topic areas observed were the physical and life science areas. There was some deviation among the sciences within the Benchmarks. Much of this deviation depended on the focus of the unit.

For example, within the Physical Setting Benchmark, one teacher taught about chemistry and another teacher motion and forces. Both of these science topics fall under the Physical Setting Benchmark, but they are differentiated at a sub-Benchmark level.

This leads to many of the same records at the Benchmark level (The Physical Setting), and to a wider range of records of the possible sub-Benchmark level. At the Benchmark level, the group may appear to be consistent, but looking at the sub-Benchmark level is a better representation of the variety and coherence of topics taught. The following chart illustrates the raw number of topics presented and the focus of those topics for all the teachers.

Table 13: Aggregate Number of Benchmarks Presented by the Teachers

Benchmarks	# of Records	Sub-Benchmark level records and comments
1. Nature of Science	144	All topics: scientific world view as the least, (3 of 3)
2. Nature of Mathematics	2	(1 of 3)
3. Nature of Technology	14	(1 of 3)
4. Physical Setting	434	All topics: structure of matter 124, motion 163, earth 89, (7 of 7)
5. Living Environment	339	All topics: interdependence of life and evolution as the least, (6 of 6)
6. Human Organism	45	human identity 15, basic functions 21, (4 of 7)
7. Human Society	36	social trade offs 21, cultural effects & behavior 13, (4 of 7)
8. Designed World	6	(4 of 6)
9. Mathematical World	9	(2 of 5)
10. Historical Perspectives	8	(3of 9)
11. Common Themes	14	systems 9, (3 of 4)
12. Habits of Mind	53	All topics: communication skills 37, (5 of 5)

There were several Benchmarks in which all the topics were covered, indicating that these Benchmarks were important topics for the teachers. Two were science content based and two were about the nature of science and how science is conducted. It was expected that substantial time would be spent on the content topics. Somewhat of a surprise was the 16% of time spent on the nature of science and how science is conducted.

The Nature of Science Benchmark includes the areas of the scientific word view, scientific inquiry, and the scientific enterprise. This use of time for the topics in the Nature of Science Benchmark is different from the findings of other studies of teacher beliefs and practice about the nature of science. (Lederman, & Zeidler, 1987) Some

closer examination of this area would be needed to determine if this finding is definitive or if the observation technique skewed the data.

The Habits of Mind Benchmark includes values and attitudes, computation, manipulation and observation, communication skills and critical response skills. Communication skills was the area most frequently area covered, as the study teachers spent a good deal of time on how to write about, discuss, diagram and report science data and information. These discussions were for student presentations for the class and reports.

These teachers all made connections to other topics of science. They were focused on their intended unit topics, and made connections to other science areas. Another way to look at this data is as combined discipline topics taught and the dispersion of those topics within the Benchmarks (Table 14).

Table 14: Observational Discipline Data for All Teachers

	Number of records	Records in areas within those Benchmarks
Nature of science, common themes, and habits of mind	197	5 of 13
Other stated content curricular Benchmarks	691	9 of 9
Non-stated curricular Benchmarks	221	23 of 45

Again the teachers tended to stay focused on their stated content and unit focus (691 records) in their classrooms. At the same time, they made connections to other non-stated Benchmarks (221 records), and included the nature of science in their curriculum (197 records). The largest area of deviation represents teachers choosing to present science that was not in the intended curriculum. An example of this type of deviation might include teaching another science topic, related or not related, to the curricular unit. These choices were made by the teacher to deviate from the stated curriculum.

This analysis of the aggregate data indicates that the teachers focused on their intended curriculum. It also shows a fairly close number of records between the inclusion of the nature of science and non-stated curriculum perhaps indicating an average content picture of science teaching. What this analysis does not provide is enough evidence to

extrapolate this pattern to other science teachers and whether these topics were related in a purposeful way to the intended content or if they were random ideas.

Because this analysis includes aggregated data, a note of caution is needed. An examination of the specific teachers and their observation data is more revealing about how each teacher handles whether the science they present is related or not, because some teachers connected more topics in science than others and the differences influence the group as a whole.

Post-Observation Interviews

The aggregated data from the post-observation interviews helped further solidify what the teachers, as a group, taught and why. The questions in the interview helped them to probe further for their beliefs and the reasons for teaching certain topics. It also includes the SMS task diagrams. Some questions were similar to the first interview to check the teachers for consistency of their beliefs over the time of the study.

As a group, the study teachers exhibited several common characteristics. They all stated similar beliefs about science:

> *Daniel: You can only interpret the data you have, and if you have this small amount of information you have to make our assumptions in that. In science there are very few answers.*
>
> *Celeste: I believe that science is the way the world works around us, but that it also is how we choose to learn about that world around us.*
>
> *Helen: I think science is discovering things around you.*

The statements about the definition of science did not seem to change much over the period of the study. This notion of discovery and interpretation of the world is also consistent with how they describe the importance of doing science:

> *Daniel: The problem solving was the filet mignon of the whole thing.*
>
> *Patricia: I think it is wonderful for them to learn that they can explore the world and feel empowered by learning how to ask questions, problem solve, design an experiment and that it is okay to be wrong in science.*

Helen: If they know how to think about how to do it themselves, they can do anything.

The role of inquiry and thinking scientifically was emphasized in their statements. Although some of the teachers taught in a more inquiry-based way than other teachers, they all used exploration and asking questions as ways to help students learn about science.

The education of these teachers was an unexpected commonality. Further probing about their education in science in the final interview was meant to see what further experience with science they had in their school and work experience that might have caused them to act differently than people who had not worked in science prior to teaching. This probing revealed some additional ideas about how they perceive the world, not just in their teaching science.

Daniel: They are going to look at the empirical data. Let's looks at the facts.

Patricia: People who are into science tend to think differently about things. They tend to be more analytical, tend to see the whole picture.

Robert: I think you see the world in two different ways, somewhat differently.

Tom: I think scientists tend to solve or use the scientific method.

These brief statements indicate that their science backgrounds influenced their view of the world and not just in their classroom activities. Robert even stated that he cannot, "touch a doorknob without thinking about the physics behind it."

There are differences in beliefs and actions of the teachers when stating and making connections in science in the classroom. Only the statements will be examined. Patricia most clearly talks about connections in science, and Tom talks about connections in general.

Patricia: I think one of the big pushes is the connection that is around. Like we spend a lot of time when we do cells on respiration and that type of thing. Also connections of how so many things are different. Mother Nature has one rule, and she just modifies it. To me everything is chemistry.

Tom: There are definitely things that are connected.

When the connections are discussed in the classroom, Tom and Helen's statements are characteristic of explanations by the other study teachers. They have almost opposing opinions about making connections themselves in their classes.

Tom: Quite frankly, I think the connections should be made in elementary schools…
Helen: Well it (the curriculum) is all linked by the cell.

Celeste stated an example about the issue of connections in sciences in reference to her own learning of science.

Celeste: I always learn better when I am making connections to things as opposed to learning things in isolation.

These different ways to discuss connections in science represent a variety of opinions. They do not agree on all aspects of connections as they interpret the idea of connections in relation to their teaching, curriculum and their own learning. Other data helps clarify these differences but it is clear that the study teachers do not have the same beliefs about connections of ideas in science.

In a related set of statements about whether students see science as connected, Patricia and Celeste are clear that it is not students that separate science ideas.

Patricia: I don't think students understand there is a difference in sciences. I think we have to tell them that.

Celeste: I think that is how kids learn.

Both Patricia and Celeste talked most articulately about making connections in their classrooms. The idea that students may also be coming to science instruction with science as a connected idea is intriguing to them.

Another area that relates to the teachers' thinking about connections and coherence in science is state and national standards. Standards have been imposed on teachers and the acceptance of them seems to vary with either how much they are used or what role the teachers think they play in classroom curricula. Statements about the role of standards vary from teacher to teacher.

Daniel: The way we do it here at school, and the way the Learning Results have it, everyone has to break up the pie.

Patricia: Standards make me uncomfortable, in science, because the spectrum is too great. Saying one part is more important than another part is difficult for me. [I am an] Advocate of depth vs. breadth so I would cut out about half of the topics in both classes so we can do more quality as opposed to quantity.

Robert: The way we got the unit in the district is we made and filled out all the Learning Results and filled the gaps.

Celeste: I am that type of person and I would teach what I love and probably teach it well, but not necessarily what's in the standards.

Helen: I think it is good to have something to go by in schools so they don't overlap so everyone gets everything.

Even though there is not a strong agreement on how they talk about standards, there is a sense that they are contributing to science education in helping teachers teach particular topics in particular grades. They all mentioned making changing in their curriculum based on the state's *Learning Results*. But no teacher mentioned the word coherence. This idea of sequence of ideas over time expressed by the teachers is part of what is meant by the researcher as coherence of science.

The final area to be discussed in this section is the SMS task completed by the teachers. Each has been described in the individual teacher descriptions. The discussion here concerns how they illustrated connections in science and whether there is a visual coherency to the ideas they say they teach. Patricia and Celeste illustrated the science they teach with very deliberate connections and a sense of sequence or coherency in how the ideas build and are related to each other. These two teachers' SMS match their interview statements well.

Helen and Daniel illustrated the science they teach with a fairly complex set of related circles. They had core content ideas including both subject and nature of science. It was not clear whether the ideas were related in specific ways such as connected by conceptual relationship or just by the curriculum topic they had to teach.

Tom and Robert illustrated the science they taught in clear ways, but with fewer bubbles than Helen and Daniel. The principal ideas were clearly identified in Tom and Robert's SMS tasks but the connections or coherency of ideas was not evident. Although

in Roberts' final SMS drawing he drew lines between the major content areas indicating that they were separate ideas.

Specific conclusions about the teacher's intent in the drawing of these SMS diagrams are difficult because they are visual representations of the teachers' thinking. The complexity of thinking does not always easily translate into a drawing. Without over analyzing them, it is possible to see how they help to further define the teachers' ideas as compared to the other sources of information in this study.

Chapter VI. Discussion and Conclusions

Introduction

This chapter discusses findings for the study, implications for teacher preparation and professional support and recommendations for further research. The overall study question is: *What is the relationship, if any, between middle school teachers' beliefs and knowledge regarding the coherence and connectedness of science concepts and their classroom practice?* And three more specific questions were posed at the outset and one additional question asked in the study for examining the effectiveness of the study:

1. *Do science teachers believe that science, as a discipline, is a connected and coherent field of study, or is it comprised of separate areas of study?*
2. *How does a science teacher's imposition of knowledge and beliefs affect the effectiveness of curriculum materials at the first levels of the TIMSS tripartite model of curriculum?*
3. *Does the belief about the coherence and connections of science impede or facilitate effective science instruction?*
4. *Was there a testing effect when assessing teachers' specific beliefs about science as a connected and coherent discipline?*

Conclusions about these questions drawn from this study will be addressed in this chapter. Each question will be discussed in a separate section. The conclusions were derived from all collected and analyzed data. It is recognized that these conclusions come from the sample of six teachers, and may not be generalizable to a total population of middle school science teachers. However, it is hoped that these resulting ideas will contribute to the larger body of research about teacher beliefs and practice, and will be explored with a larger sample of teachers.

In addition, comments on the limitations of the study, recommendations for future research, and the implications of this study for the field of science teacher education are included.

Middle School Teacher Beliefs About Science as a Discipline

Generalizations concerning the teachers' beliefs about science as a discipline are formed from a comparison of the survey and the pre and post-observation interviews. The teachers' SMS will be used as the way to describe the schema or conceptual belief structure of the teachers. This is consistent with Gess-Newsome's approaches to describe teachers' thinking about science (1992). In general, the teachers' SMS can be described as a balance of specific content, and nature of science and habits of mind. The specific content areas identified here by the study teachers such as cells, chemistry, and evolution are consistent with textbook classifications and can be found in the Project 2061 Benchmarks. The topics encompassed by the nature of science and habits of mind are easily identified in the Project 2061 Benchmarks, but are not clearly identified in textbooks or the curriculum materials used by the teachers. The content terminology identified was generated by the teachers and not presented to them in the interview or with terms on cards. The content described by the teachers seemed to originate more from their own beliefs about their knowledge, doing and communication of science rather than from their curriculum.

Content

All teachers were able to talk about the specific content and the connections between the content that they taught. The degree of specificity and number of connections among science topics varied among the teachers. For instance, Tom talked about core ideas or a base of knowledge that students needed to know. Tom's base was chemistry. Patricia also talked about chemistry as being everywhere, but she was specific about how and where concepts within chemistry connected to other areas of science she taught, and how they helped students build one idea on another.

The differences between Tom and Patricia are subtle, but important. Tom gave the sense that a separate prerequisite knowledge is needed before students can connect one set of ideas to another set of ideas, while Patricia gave the sense that ideas in science may be more fluid in that they are already connected. She further believed that by introducing

new ideas at various points and coming back to them, the connections among the ideas could help students understand the unit topics as well as the larger ideas in science.

Other teachers such as Helen talked about the importance of connections in science, but struggled to provide them in her classroom. Her SMS clearly laid out the topical content, but did not show the deliberate relationship between the ideas as can be seen with Patricia's and Celeste's SMS diagrams. Daniel also talked about the connections of science. He had students select and complete four independent projects. This allowed a wide range of science topics to be introduced into his classes. In his SMS diagram, the connections were not specific. The importance of the nature of science and habits of mind were not as well represented in his diagram as they were in his interviews and classroom observations. Helen and Daniel's beliefs about science being connected seemed to be present, but the translation into practice was not.

The conclusions about the teachers' beliefs about the coherence of the science are drawn from their pre and post interviews and SMS tasks. Generally, each teacher stated that she/he believed that there was a sequence and relationship among the sciences they taught. When looking at all of the evidence, the researcher saw that some teachers' ideas were very clear and others were not. For example, Patricia and Celeste drew diagrams of the science they taught in a way in which the relationships among ideas were clear. Patricia drew a triangle with science knowledge building on itself over time in the class. Celeste's second drawing used Venn diagrams showing the overlap and how the ideas connected and intersected, with her final goal by the end of the year placed in the center.

The other teachers were less clear in their visual representation of the coherence of science. Robert separated his topics by location and with lines. Helen, Tom and Daniel linked different science ideas with lines, but these lines had no arrows indicating direction, order or strength of conceptual relationship.

When comparing these SMS diagrams with what the teachers said in their interviews or with their classroom practice, another pattern became apparent. Because the teachers were clear about what they were teaching about knowledge building conceptually over time, their approach might be characterized as coherent. At the same time, the type of topic connections were limited and restricted. For example, Robert talked about making connections to other areas, but made very few of them. He stuck to

his content area and only made connections to real world examples of the content he was teaching. These types of limited connections might also be characterized as coherent because he did not allow for divergent ideas in his lessons. The ability to generalize about these teachers' beliefs about the coherence of science is limited because of the complexity of determining what coherence is from the data collected. Coherence may be established within a narrow topic focus and with many connections, depending on how broadly defined the concept of coherence is. It is challenging to determine both the characteristics of the connections and coherence in science.

Frameworks

The teachers studied have mental frameworks or schema of the science they teach. These frameworks can be described from data in the interviews and SMS diagrams, and help categorize each teacher's depth of thinking about science and science teaching. When the teachers were asked to complete the SMS task, several had difficulty getting started. Robert, Helen and Celeste said they had never before thought about the science they taught in terms of conceptual map. After the SMS completion, Celeste noted that she found it beneficial to do this reflection as it helped give a sense of context and coherence to the science she taught. When asked to draw her SMS, Helen drew a storyboard type diagram showing a year-long sequence, which was helpful in depicting the coherence of her curriculum over time but not the relationships among ideas. The visualization in a two-dimensional map of the science taught over a school year and how those ideas were related seemed to be a new idea for these teachers.

Because concept maps can be drawn in several different ways, it is difficult to generalize about the challenges for these teachers in drawing a concept map. It is possible that they had little or no experience in drawing a concept map. However, there was a general pattern for this group that creating a SMS drawing was a fairly new activity. This is similar to other studies of science teachers (Gess-Newsome, 1992).

Another aspect of the mental framework was a challenge for the teachers to articulate. When asked about whether they had a philosophy of science or whether there is a culture of science, many of them hesitated and asked for more clarification. Patricia,

Tom and Robert gave a response and then asked if they were responding correctly. When the teachers were questioned about the teaching of science, each had a lengthy response. The difference between the two responses is indicative of the difficulty and even the inability of these teachers to separate the ideas of science from the teaching of science.

An analysis of the interviews identified eight major strands of ideas related to science and science education. When the strand topics were matched to the earlier described science knowledge frameworks of Roth and McGinn (1998) and by Shulman's education framework (1986) in the literature review, the teachers' ideas fell mostly within the science education framework.

Table 15: Teacher Strands Matched to Conceptual Frameworks

Teacher Stated Strands	Conceptual Frameworks Categories
Preparation to Teach	Science Knowledge
Instructional Issues	Science Education
Challenges to Teaching	Science Education
Thinking about Science	Science/Science Education
Standards	Science Knowledge/Science Education
Materials	Science Education
Choice to be a Teacher	-none-
Most Important Topic	Science/Science Education

A final area of inquiry concerned the origin of their knowledge about science and science education. When asked about the origins in the final interview, all of the teachers said that they have held their beliefs of science for some time. They mentioned the importance of their college courses for science ideas, but for Patricia, Celeste, Helen and Daniel, it wasn't until they actually had the opportunity to engage in the science while teaching that they felt that they better understood science as a field of study. When they talked about how they used science, they became very engaged and enthusiastic. This enthusiasm did not transfer when they talked about their college courses. Only Helen and Tom talked about those courses as being exciting, and for Helen it was just one course.

Tom talked about using his knowledge of geology in various outdoor adventure jobs. Tom was enthusiastic about just one instructor who paid a lot of attention to him

and helped him get through the course work. The apparent lack of excitement by all of the teachers at the collegiate level might indicate that the study teachers had a previous interest in science and perhaps a SMS prior to their post-secondary education because they continued with science even though the courses were not engaging.

When asked about what they thought of science during high school, the study teachers had little to say other than what they were taught seemed to be what science was about. Patricia, Tom, Helen said they had always had an interest in science.

All of the teachers were asked about how they kept their knowledge in science current. The responses consisted of college courses, workshops, science education and science periodicals. They all participated in on-going learning in science and science education. Robert, Celeste, Tom, Daniel and Helen talked more about learning about science education, while Patricia talked more about learning in science. There was some frustration expressed by most of the teachers that they couldn't find many learning opportunities that addressed both areas.

The explicit identification of their own personal SMS was new for many of the teachers, and, as Celeste said, she had never before thought this way about the science she taught. The process of self-identification or articulation of their SMS might be an important process for teachers in understanding their own beliefs.

Summary

The SMS or the components from which they are formed occurred over time and were affected by college courses, working in science, teaching science, and experiences outside of school. This interaction and the fluid formation of their SMS led to the conclusion that SMS are dynamic over long periods of time. However, the SMS were stable over the period of a school year. Tom and Daniel spoke the most about how they saw their colleagues changing their thinking about science. Each one was now thinking about changing his ideas but was reserving judgment and letting things evolve. The reflection on the SMS for each teacher seemed to be an important and original idea for them. It appeared to help the teachers look at the connection and coherence of the science that they taught.

The SMS is tightly linked with science and with the teaching of science. Other researchers have suggested this linking of science and the teaching of science by teachers as typical (Hauslien & Good, 1989; Brown, Collins & Druguid, 1989). Similar findings (Gess-Newsome, 1992) indicate that the teachers' belief frameworks are similar to those of other science teachers. The connection between science and science teaching suggests that pedagogical content knowledge is a powerful and important aspect of teaching, because teachers link the content and the teaching of content whether or not appropriate, based on their past and current learning and experiences.

Imposition of Beliefs And the Effectiveness of Curriculum Materials

The degree to which the teachers' beliefs affect the effectiveness of curriculum materials is great, but the specific reasons and situations for each result were more difficult to determine. The efficacy of curriculum materials in this report means the implementation of the materials as they were written. The quality of the students' learning and the extent to which the students used the materials were not a part of this study and hence will not be discussed. From the combined sources of data, there were four types of interactions of beliefs and effectiveness of curriculum materials: teacher development of their own materials, teacher modification of existing materials, other classroom variables, and no interactions.

All of the teachers expressed some frustration with textbooks and other curriculum materials. Only one teacher used a textbook even after saying he didn't use the textbook. Patricia and Daniel developed the curricula for at least one of the units observed. They stated that they were not able to locate existing curriculum that provided the type of learning sequence and content they wanted, so they developed their own. Tom, Helen, Celeste and Daniel made modifications to existing curriculum. Instead of developing new materials, they would change or supplement with other curriculum that better matched the sequence and content they wanted to teach. The modifications varied from changing the sequence to using the materials as a reading resource for the students. They used a wide range of additional materials to supplement text curriculum or their own instructional materials. When asked about the content and sequence of the

curriculum they taught, they all responded with comments that this was the best order for the students to learn the science. None of the teachers taught the same unit, so no comparisons could be made about a specific topic or sequences with which it was taught.

Tom and Helen talked extensively about the limitation on their teaching due to other classroom variables. These included no tables, very little equipment to do hands-on activities, rugs, overcrowding in a small classroom, and little funding for additional equipment. Because of these limitations, Tom and Helen had to modify the curriculum materials they had. The other teachers did not raise these concerns.

Another area of modification was in the area of teaching science. Daniel, Helen, Celeste, and Patricia all had students working on projects with some sort of classroom presentation. These projects emphasized doing and communicating science. Robert also emphasized doing science, but only in the context of specific laboratories he had planned. The content emphasis of these project-based units, even though there was a topical focus, was on students' learning about the nature of science and habits of mind.

Robert followed the curriculum material's content sequence fairly closely. His only modification was in the area of teaching science. He talked about developing and having students do qualitative laboratories before the quantitative ones. He stated that he believed the students needed to experiment and play with the equipment first before he held them accountable for proper use of and results from a quantitative laboratory.

Except for Celeste and Patricia, the teachers' modifications were more in the area of teaching science rather than in the science content. Both Celeste and Patricia said they taught the science they did because they felt it helped the students to best learn the science and that curriculum materials did not help them in the design of what they taught. Celeste used a textbook as a base while Patricia did not. The part about the book that Celeste liked the most was the pictures. She felt that they helped students see the things they were learning in the classroom.

Summary

These teachers exhibited a variety of interactions with the curriculum materials, and this is similar to suggestions by other researchers (Schmidt, et al. 1996). These teachers seem to be similar to other science teachers.

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The variation in interactions is suggestive of other aspects of the teachers' thinking about science and science teaching. Patricia and Celeste, who made the most changes, also displayed the strongest tendency to connect science ideas and to provide more descriptions about the coherency of the science they taught. This characteristic could be indicative of most divergent influence of beliefs on the use of existing curriculum. Because of the complexity of the development of curriculum materials and teacher beliefs, this finding might also indicate poor quality curriculum materials. Other teachers such as Robert used a text almost as it was intended. It is difficult to determine even when asked whether Robert followed the textbook because the content was in agreement with his beliefs, or whether the text influenced his beliefs so that his thinking was congruent with the text. From this sample, the range of interaction with curriculum indicates the large influence of teacher beliefs on curriculum materials.

The complexity of what is needed for science teaching today is apparent in a recent statement by a researcher; "If teachers are to teach the new science curricula successfully, their subject matter should include the structures of science, not just the structure of physics, or chemistry or biology, and not trivial understandings of the structure of mathematics and engineering as well" (Carlson, 1999. p.141). Only Patricia and Celeste discussed the importance of the relationship among the science topic areas and explicitly displayed relevant behaviors in the classroom with the use of their curriculum materials.

Beliefs About the Coherence and Connections of Science: Do They Impede or Facilitate Effective Science Instruction?

The only consistency in the teachers' statements about the connections and coherence of science was in what they stated in the first survey and pre-observation interviews. In the second interview, Tom and Robert indicated that their beliefs changed about connections in science to be less supportive of the idea than what they had responded in the original survey. Their beliefs did not seem stable concerning the connections in science. There was a lack of consistency between the interviews and the survey. The other teachers were more consistent in their beliefs about the connectedness

in science, but again some variation occurred when their practice was observed. In the classroom observations, Helen and Daniel exhibited few connections to other areas as might have been expected from how they described what they taught in their interviews. Only Celeste and Patricia discussed their SMS tasks in the interviews and then exhibited classroom practice consistent with what they said about the connections in science.

The coherency of science was difficult to determine from the interviews, but indications of coherent thinking were possible from an analysis of the SMS diagrams and how the teachers taught science in their classrooms. The SMS diagrams illustrated coherent science by showing connections to related topics and demonstrating strong relationships between the ideas mentioned. Celeste and Patricia each drew an SMS showing a coherency of ideas. They included arrows with directions and through a pyramid or Venn diagram, the relationship of ideas to each another. Helen drew a SMS diagram that showed a sequence or possible building of ideas based on a sequence. Robert's SMS diagram created divisions between topics so that any coherence in the ideas would be found in the focused topic and not between the topics. Daniel and Tom's SMS diagrams were less clear about the way the ideas were connected and the relationships among them. There were no arrows and little size differences between ideas to determine if one idea was more important than another.

The range of topics presented in the classroom and whether the topics were part of the stated or non-stated curriculum varied by teacher. Daniel and Helen focused on their stated curriculum. All of the ideas presented were directly related to the topic used in the class. Daniel had an additional emphasis on the nature of science and habits of mind. This was supported by the recorded stated curriculum. The coverage of content in Daniel's observations was almost half of the other teachers while the percentage of curriculum coverage of the nature of science was higher than that of the other teachers.

Patricia and Celeste focused on the stated curriculum with some additional emphasis on non-stated curriculum topics. Their use of non-stated topics seemed to be directly connected to the existing curricular topic. Celeste included more coverage of the nature of science and habits of mind topics than did Patricia. Robert and Tom almost exclusively focused on the stated curriculum and made few unrelated connections. The

presentation of a topic for them was always directly connected to the topic at hand; no general connections were made.

These teachers' connections and coherency of science can be seen in a summary table, which places them by their aggregate tendencies to teach science in particular ways recorded by an analysis of their classroom, interviews and SMS diagrams. It is a generalization based on the units observed and the period over which the study was conducted.

Table 16: Connections and Coherency Table of Teachers in Study

	Non-coherent topics	Coherent topics
Connected topics	Helen, Daniel	Celeste, Patricia
Non-connected topics		Robert, Tom

Summary

The teachers exhibited a range of beliefs and classroom practices about the connectedness and coherency of science. How these two variables relate to the effectiveness of instruction in science is complex, but from the data collected here, some indications exist that theories can be made about the relationship between teacher beliefs about the connections and coherency of science and teacher's practice.

Based on national standards, to achieve high quality science instruction, science needs to be taught in a connected and coherent way. Using this idea as a guide, only two teachers, Celeste and Patricia, exhibited consistent beliefs about the connectedness and coherency of science and displayed those beliefs in their practice. The other four teachers had a range of ideas, some more stable than others, but they were not consistent across the survey, interviews and SMS task. This group of teachers did not display science instruction as a connected and coherent discipline. There are many reasons for the variation in beliefs from experience, courses and classroom variables, but consistent and stable beliefs about connection and coherence seem to be needed in order to have them exhibited in the classroom.

A final note is needed about the teachers' beliefs about their practice. It is clear that they do not teach science in isolation from other factors in the schools. All of them stated that many factors influence their approach to teaching science outside of their own thinking. These included the school environment, student body and behavior, curriculum and standards, available classroom materials and finally the personnel in the school, either other teachers or principals. Parents were mentioned by all of the teachers, but usually in the context of inviting them into the classroom. The parents rarely influenced or affected how or what is taught in the classroom. The intent in this search for elements that influence teaching was to clarify the complexity of teaching.

Testing Effect in Assessing Specific Beliefs About Science

There is evidence of the stability of the study teachers' SMS, and that participation in this study did not change their SMS and/or practice. All of the teachers seemed to feel that their SMS existed prior to this study. For Tom, Celeste and Robert, evidence for this conclusion can be derived from the comparison of the pre and post observation SMS task completion. For these teachers, their SMS was relatively stable with only some refinement and the teachers, themselves, did not see much difference in the two recorded SMS tasks. All but Celeste stated they had thought about the science they taught in this fashion. Celeste seemed more intrigued about the visual format of the SMS task and how it can facilitate reflection of the science that she teaches. She did mention that she and her colleague at school had been reviewing the science curriculum and making adjustments in content and sequence. At the same time, Celeste, Daniel, Tom, Helen and Patricia talked about their beliefs about science prior to their teaching. This shows that they had a SMS prior to teaching and that the SMS task for Celeste may have helped her organize her thoughts about the science she taught.

In addition to the SMS task, each of the teachers talked openly about her/his beliefs in science and science education. Each talked about a "way of thinking" in science and about the sequence to the science he taught. Helen said that she felt the sequence of topics she taught built on each other. She started with the smaller knowledge component of the cell, and moved into larger human systems. Patricia and Tom talked about

chemistry as the starting point for the science they taught. Robert was less confident in the sequence of what he taught, but more focused on the content of an area of science. He talked about doing mechanics for most of the fall before moving into the next unit. This agrees with his SMS diagram where his topical connection was in the physical sciences and not across science topics.

Tom talked about connections being important in science, but he later said that the connections should be made in elementary school. Then he stopped and talked about the high school teachers who were now trying an integrated course; he was going to wait and see how it was going before he would consider such a change. His SMS was established, but was being tested by teachers at other levels in his school district. The relative stability of the SMS of these teachers is consistent with other findings of science teachers (Gess-Newsome, 1992).

Evidence for the potential of a testing effect in this study was sought. Each of the teachers was asked about her/his beliefs about science and science education prior to and after the observations. There was consistency between the two interviews. The teachers were asked if they changed anything they taught during the classroom observations; they all stated that they changed nothing. As a result of an analysis of this data, no evidence of testing effect was found.

For example, when challenged about the sequence of science topics taught, Tom and Patricia stated that they thoroughly thought out the content sequence and activities according to how they believed they would help students build knowledge over time. They both referred to coming back to concepts over and over as they progressed through the year. This consistency in the teachers' SMS seems to indicate a relative stability in their thinking over the period of the study. Tom, Celeste and Robert stated that the completion of the SMS task did not affect what science they taught. There wasn't greater congruence of SMS for the teachers who completed the pre-observation SMS task prior or for the teachers who completed only the post-observation SMS.

Finally, when examining the practice of the teachers and their SMS diagrams, the researcher found similarities. The manner in which Tom, Celeste, and Robert taught the science in class was similar to how they talked about it in their interviews and in their pre and post SMS tasks. For the other teachers, the same similarities existed between how

they described their SMS and what they taught as the teacher, but some variations did exist.

Daniel had the greatest deviation from his illustrated SMS, but only in the area of the nature of science and habits of mind. He emphasized these concepts in class and in his interview, but the scientific process was not well represented in his SMS diagram. The scientific process area was not larger or more connected than the other topics he taught. Helen, Tom and Robert did not display in practice the connections they talked about in their interviews, and their SMS diagrams did not show those connections. This triangulation of data among the different sources helps characterize the beliefs and practice of the study teachers.

These results indicate that the SMS of these teachers was present prior to the study and remained stable during the study. These findings are similar to other studies except perhaps for Celeste, Patricia and Helen. These three teachers were fairly new to teaching, with six years or less experience. Other studies indicated that preservice and new teachers (Gess-Newsome & Lederman, 1991) had an unstable SMS. The suggestion was that preservice and new teachers had not been placed in a teaching situation long enough to form a solid SMS. Is it the teaching of science that stabilizes a teacher's SMS?

The question can be asked, "Does teaching one to six years, and in the case of Helen, two years, establish a stable SMS?" One factor about these teachers that may be different from the typical preservice teacher in the other studies is that the study teachers all had a science major in college and worked with science as a career prior to teaching. The focus on the formation of SMS for teachers is interesting in terms of the factors that form it and if it can be formed prior to its application in teaching. This study indicated that the SMS can be formed prior to teaching and that a strong content background may be one of the factors that help teachers form their SMS.

Limitations of the Study

Several aspects of this study limit the possibility of making generalizations from the findings as reported: the representativeness of the teachers as compared to the population as a whole, the number and manner of the classroom observations conducted,

the way in which the teachers' SMS were conceived and derived, and the inability to make developmental claims based on the data collected. Each limitation will be briefly discussed here.

First, the population of teachers was specifically identified for their beliefs, and subsequently for their geographic location and its convenience to the researcher. They were not randomly selected. Considerations of the teachers as representative of the total middle school population were made only in their final identification. They did span the range of middle school grades, six to eight, and years of experience teaching, three to 19+ years. They all came from Maine. Thus, in order to strengthen the generalizability of the findings, a much larger sample of middle school teachers would need to be studied. In addition, this study focused on the nature of middle school science teachers' SMS.

No generalizations can be made concerning the SMS of teachers in other subject matter areas, or the limitations on the implementation of their SMS on classroom practice. The generalizability related to SMS may not be a major issue as the context for teaching; personal histories of teachers seemed to influence the results. However, even with these factors, there is little evidence to suggest that the teaching context and histories of these teachers were so unique as to preclude these findings as a part of current theories about SMS or future investigations of SMS with other teaching populations.

The second area of limitation was the number and nature of observations. The classroom observations constituted less than 10% of the total number of teaching days, although attempts were made to mitigate such limitations by analysis of curricular materials and focus on the patterns of science taught rather than how it was taught. The findings about SMS were based on the observed units conducted. Had a different sample of lessons been observed, the results may have varied to an unknown degree.

Concerning the schedule of classroom observations, speculation surfaces about whether other lessons - particularly those at the end of the year - would be more connected and coherent. One assumption in this study was that teachers interpret the science they teach based on their beliefs, which would not change during the year. If teachers think about a course as a sequence that follows a yearly plan, rather than as unit blocks, then the schedule is not a limitation. However, findings from high school biology teachers (Gess-Newsome, 1992) and some of the teachers in this study, question the

assumption made about how teachers interpret the science in a course or through the year-long curriculum. Additional research may need to be conducted to determine the appropriate unit of analysis for the study of teachers' conceptions of content.

The third area of concern is the method for identifying and describing of the teachers' SMS based on classroom observations and materials. The design of this study focused on a specific area for observation and sought incidences of content instruction only and then the connection of content topics to one another. The relationship of the connections was also important for a more coherent science course. This methodology may have led to a SMS that is more connected than the teachers themselves knew or believed. Thus the inferred SMS may represent levels of complexity and relationships greater than may have actually existed. The bias of the researcher in the choosing of the sample of teachers was that they would make connections in the science content and that there would be a purpose for those connections. Though this generally seemed to be the case, (the assumption was that the nature of the connections led to a varying level of coherency in the science being taught) further investigation may be warranted to explore the nature of connections in science.

The illustration by the teachers of their SMS may be an inadequate method for representing the complex interactions and relationships of the nature of a teacher's SMS. Other researchers have used this methodology as a basis for understanding a teacher's SMS; yet a two-dimensional drawing may be too simplistic a tool for this purpose. In addition, several of the teachers in this study stated that they found it difficult to make the SMS drawing and that they had never thought of the science they teach in this fashion. Unfamiliarity with the task could have reduced its effectiveness. However, the beliefs expressed in the SMS task were used as one source of the teachers' SMS and as a comparison to what they actually taught, rather than as the only method for collecting their SMS.

A final limitation is the ability to make any statements about the developmental differences of the teachers and whether claims can be made about how that affects their SMS. Teachers in this sample represented a variety of years of teaching experience, but no claims can be made for a developmental process for an individual teacher. The information gathered here can be used to inform researchers conducting teacher

development studies. Specifically, information about the difference in development among teachers with and without strong content preparation and how that knowledge is translated with experience by those teachers would benefit future research in teacher preparation and new teacher support.

Implications and Recommendations for Science Teacher Education

Some recommendations for future research have been previously suggested in the limitations section of this report. These include the methodology of the SMS task, further exploration of the nature of connections in science in a SMS, the appropriate unit of analysis for the study of teachers' conceptions of content, and the difference in SMS development among teachers with and without strong content preparation. Additional areas of research are apparent from the results of this investigation as are implications for both preservice and inservice teacher education.

The most immediate implications for research and teacher education include the methodology for assessing the science taught by teachers, the meaning of a strong content background and its effect on SMS, the relationship between connections and coherency in science, and the stability of the SMS of teachers in the context of reform initiatives in science education.

The specific identification of the connections and coherency of science content that is taught is one part of the practice of teaching that has not been previously isolated. The methodology for assessing the science taught by teachers used in this investigation was developed by the researcher specifically for the purpose of examining the content in isolation from the instructional components of teaching science. Gaps existed in the data when the teacher was not teaching science. This would be an area for further exploration.

Do teachers with a clearer SMS use their instructional time differently than teachers with a less stable SMS? This use of time is an instructional issue and was not examined in this study. However the implication for teacher education is on the formation of a stable or a particular type of SMS so that their instructional time can be better used. This would lead to more attention to the formation of SMS in science methodology classes for new teachers and to the identification of teachers' SMS in inservice programs.

The methodology to identify the science taught in the classroom used the Project 2061 Benchmarks as the framework for organizing the topics. Further research could be conducted on the correlation of the science in the Benchmarks and the National Science Education Standards and whether the use of the Benchmarks biased the way the content is collected as compared to the use of the NSES. The NSES categorizes science by the traditional content areas of life, physical, earth science and inquiry, whereas the Benchmarks do not. From the outset, the organization of science nationally as a discipline is not congruent, which might affect the way the data is perceived. Since this investigation was looking at the connectedness and coherency of science, do the two documents organize science in conflicting ways, which affect the data organization?

A final recommendation about the methodology used in this study for further research is the unit of measurement. Two minutes was selected as an appropriate interval for minimum topic "coverage" in which students were expected to have learned something about the concept. The teacher had intentionally shifted from the stated content to the new unstated content and stayed on the topic for the two minutes. The recommendation would be to research whether the unit of measurement should be larger or smaller.

The implication of this research for teacher education concerns the length of time in which a specific use of a content topic helps or hinders learning of science. What is the right length of time needed to draw students' attention to a science concept connection so that they understand the link to other ideas, without necessarily knowing all about that particular concept? Further focus in a science methodology course on the time and connections in science is needed in order that students learn of the connections in science. How do these connections lead to a better understanding of the coherency of science?

Another recommendation for research concerns the meaning of strong content background and its effect on SMS. Do the science courses or the ongoing learning of science by the teacher help or hinder the development of their SMS and the role of working or doing science in the development of a SMS? This question is important to the study of middle school teachers with a strong science background. Experts in a discipline are able to organize the nature of their knowledge more quickly and efficiently than non-experts (Mestre, 2001; Bransford., Brown., & Cockling, 2000).

Five of the six teachers had actually used their science knowledge in the work force prior to teaching. The only teacher who did not practice science in a job had the most isolated and divided SMS of all the teachers. Research into the effect of doing science on a teacher's SMS and the courses they also had taken would help explain the importance of this factor on SMS development. Is the doing of science more powerful in helping teachers form a SMS that is connected and coherent than taking many science courses?

The engagement in science as an area of knowledge is included in both the science and science education frameworks for what an individual knows in science. Research in this area has implications for both the science teacher education method and the science content classes. Greater attention is needed to the role of doing of science for new teachers in both types of teacher training classes. Helen, for example, who was a medical technician for several years, stated that the most powerful science course she took was a chemistry class that was inquiry-based where she had to discover answers to questions. She stated that this course was very different from all of her other science courses. Doing science, as a prerequisite to teaching science may be an unnecessary component of teacher preparation, but a closer examination of its role in developing a connected and coherence SMS is warranted.

Research into the importance of the connections and coherency of science and the relationship among them for forming science SMS is under-explored. Past research has found that teachers represent the character of science (Kennedy, 1997 & 1998) not just the content of science. The finding in this investigation about the characteristics of science as connected and coherent in a science classroom raises some interesting new questions.

How may connections in a science topic lead to an effective curriculum?

What is the nature of those connections?

Are the numbers of connections tied to specific topical areas?

Can you have a coherent curriculum with no connections?

Each of these questions suggests further areas of research.

Such research has important implications for the preparation and ongoing support of teachers. In supporting the vision of national standards, teachers will need to be

assisted in learning more about how science ideas are related to each other and the nature of those relationships. In the sample of teachers in this study who stated that they believe that science is connected, only 1/3 of those who taught science made those connections. The strength of SMS to influence what is taught should not be understated. Attention to this area would assist content courses methodology and provide support for practicing teachers.

The stability of a teacher's SMS in the context of reform initiatives in science education is another broad area for further research. Even science and educational policy books, Consilence (Wilson, 1998), Finding Order in Nature (Farber, 2000) NSES (NRC. 1996) Benchmarks (AAAS, 1992), Turning Points 2000 (Jackson & Davis, 2000), and How People Learn (Bransford., Brown., & Cockling, 2000) all reference the importance of making connections of ideas and of providing a coherence of learning to ensure its quality. Put more precisely Kennedy states: "To manage classroom discussions of the sort reformers envision, teachers would need enough knowledge of the subject matter to recognize which questions are likely to be fruitful and which are likely dead ends. That in turns suggests that they must understand how the various ideas in a subject are interrelated and which ideas are relatively more important than others." (1998. p. 260)

Science is always changing. If students are to learn science better, should they learn specific isolated facts or learn science ideas linked to other ideas, which helps to form a framework for thinking about science and assimilating new science ideas? Further research about the role of student science learning that is connected and coherent is needed to support the recommendation made by the broad policy and research documents so that teachers and teacher educators will be able to incorporate improved practice in their classrooms.

The implications of this research area are for both content-specific and content methodology classes for teachers. Greater attention will be needed to support the learning of science in ways that are aligned with this research. For the inservice teachers, the identification of specific SMS may be needed to determine the most appropriate route for support. Any sessions designed for practicing teachers may be better based in terms of not only their prior knowledge about science, but also how they think about that science or their SMS.

Since the formation of the type of SMS seems to influence teaching practice and methods for the formation of effective knowledge structures, there are additional implications. They include the influence of prior knowledge on the stability of SMS of teachers in the context of reform initiatives in science education SMS and the ease with which SMS can be changed or adjusted through interventions or by teaching.

Science education reform initiatives - as described in the introduction section of this study - have been occurring for many years. Have reform initiatives addressed the SMS of teachers and should they? This area is largely unexplored. Teacher knowledge in this regard is documented as science knowledge and as science education frameworks. The lack of attention to the development of SMS has seemingly led to the individual development of the SMS while ignoring the possibility of addressing various aspects of science knowledge framework areas to support the common development by teachers of a more comprehensive SMS. The inclusion of science and pedagogy by Shulman in the development of pedagogical content knowledge has been an important step toward the connection of these domains. Further research needs to be conducted to determine whether interventions and improved teacher education programs can better address the formation of SMS that include these specific aspects of science education knowledge.

In addition to the areas just described, the complexity of teaching and the isolation of those factors represent an ongoing concern. Does reflection by teachers affect their own development of SMS? This question is asked by Gess-Newsome (1992), but is teacher reflection on the connectedness and coherence of science typically practiced in schools? Celeste spoke positively about the opportunity to reflect on the science she taught and how it was structured, but this activity seemed to be something new. The time and activities supported by schools could potentially affect a teacher's SMS. The daily, weekly and yearly activities in a school should be examined to see how they influence the SMS of teachers. This would be helpful in large school reform initiatives to address the need for non-classroom time for teachers, and what the focus of that time might be.

Finally, many of the results of this study suggest that teachers' ability to teach science in a connected and coherent fashion may be tied to the teachers' mental framework for understanding science, their autonomy from limiting curriculum materials while paying attention to standards, and their reflections on what they are teaching and

why. Further research in these areas will help isolate and mitigate outside influences and lead to a more effective teaching work force, while promoting the ongoing support of practicing teachers.

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APPENDICES

Appendix A: Introduction Letter

March 31, 2000

Dear Colleague,

I am currently a Ph.D. student in the Educational Studies program at Lesley College in Cambridge, Massachusetts. I am conducting a study of how Maine middle school science teachers design, plan and conduct their courses. As a former middle school science teacher, I know that there are many factors influencing decisions for teaching a particular lesson or unit. It is well documented that there are a variety of effective ways to teach depending on the day, the topic or particular students. However, educational researchers have failed to ask teachers about their underlying thinking about the science in the lessons for which they were observed.

The purpose of the study is to identify aspects of the decisions about and practice of designing, planning and teaching science. Middle school science is an intriguing level to study because of the many ways science can be taught. For this study, I intend to collect data concerning both the current academic semester as well as the coming fall semester of the 2000-2001 school year. As a part of this study, a survey is being sent to all Maine middle school science teachers.

This research will attempt to collect a rich and varied base of sources representing the ways in which middle school science teachers accomplish their instructional goals. I am hopeful that this information will contribute to a greater understanding about the diverse and dynamic thinking of teachers and students in middle school science classrooms.

The first step in this research process is to have middle school science teachers complete a survey. It is enclosed here. **Please complete and return the survey in the enclosed envelope by April 15, 2000.** It takes about fifteen to twenty minutes to complete. You are not required to identify yourself.

In addition, eight teachers with a range of teaching experience will be invited to participate in a more in-depth set of follow up interviews and classroom observations. **If you would like to be considered for participation in the follow up study, please identify yourself when completing the survey.** The following is a description of the follow up study:

A. Completed survey (enclosed)
B. Two hour interview (in the spring or summer of 2000)
C. One hour pre-instructional interview (1-2 weeks prior to observations of unit)
D. Classroom observations with audio tape recording
E. Classroom materials used in the observed lessons/unit (e.g. handouts, exams, lesson plans.).
F. Two hour post-instructional interview

I am looking forward to this study and to learning more about the complex job of teaching science. If you have any questions, you may call me at my office (287-6491) or at my home (725-2097). You may also contact my dissertation advisor, George Blakeslee (800-999-1959 ext.8488), for information or references. Thank you for your time and consideration of this project.

Sincerely,
Francis Eberle

Appendix B: Middle School Science Teacher Survey

Demographics

1. Male ___ Female ___

2. Age _____

3. Current teaching level. *(Check all that apply)* Grade 6___ Grade 7___ Grade 8___

4. Years of Teaching: 1-4 yrs___ 5-8 yrs___ 9-12 yrs___ 13-16 yrs___ 17 + ___

5. Circle all of the primary science areas you are responsible to teach:

a. Life Sciences b. Physical Sciences c. Earth Sciences d. Space Sciences

6. Circle any other area you currently teach:

a. Language Arts b. Social Studies c. Mathematics

Read each selection and select ONLY ONE response for each of the statements that best reflect your position.

I. Beliefs and Knowledge Section of Questions

1.Defining science is difficult because science is complex and does many things.

But mainly science is: *Please read from A to G, and then choose one.*

A. A study of fields such as Biology, Chemistry and Physics
B. A body of knowledge, such as principles, laws and theories, which explain the world around us (matter, energy and life).
C. Exploring the unknown and discovering new things about our world and universe and how they work.
D. Carrying out experiments to solve problems of interest about the world around us.
E. Inventing or designing things (for example: artificial hearts, computers, space vehicles).
F. Finding and using knowledge to make this world a better place to live (for example: curing disease, solving pollution and improving agriculture)
G. An organization of people (called scientists) who have ideas and techniques for discovering new knowledge.

2. Some educators have suggested students will better understand science if they first grasp certain fundamental concepts applicable across science areas. **Your position basically is**: *Please read from A to E, then choose one.*

A. It is best to have students learn **smaller and separate ideas** of science such as cellular structures in biology as they are more manageable to learn.

B. It is best for students learn separate components of science (such as cellular structures in biology) and have an opportunity to **apply the separate ideas** in new situations as an assessment.

C. It is best for students to learn science in a real world **context**, such as reproducing phenomenon in experiments so they see the science concept represented.

D. It is best for students to learn science through **connecting** science concepts in different contexts such as the flow of energy in ecosystems and photosynthesis as they build knowledge about the common aspects discipline of science

E. It is best for students to learn science ideas in an **integrated** way such as with themes as students would be encouraged to make connections to **other subject** areas and the science ideas are parts of a theme.

3. Scientific observations made by competent scientists will usually be different if scientists believe different theories. **Your position basically**: *Please read from A to E, and then choose one.*

A. Yes, because scientists will **experiment** in different ways and will notice different things.

B. Yes, because scientists will **think** differently and this will **alter their observations**.

C. Scientific observations will **not differ** very much even though scientists believe different theories. If the scientists are indeed **competent** their observations will be similar.

D. No, because observations are as exact as possible. This is how science has been able to advance.

E. No, observations are exactly what we see and nothing more; they are the facts.

4. When scientists classify something (for example, a plant according to its species, an element according to the periodic table, or energy according to its source), scientists are classifying nature according to *the way nature really is.* Any other way would be simply wrong. **Your position, basically:** *Please read from A to F, and then choose one.*

A. Classifications match the way nature really is, since scientists have proven them over many years of work.
B. Classifications match the way nature really is, since scientists use observable characteristics when they classify.
C. Scientists classify nature the most simple and logical way, but their way isn't necessarily the only way.
D. There are many ways to classify nature, but agreeing on one universal system allows scientists to avoid confusion in their work.
E. There could be other correct ways to classify nature, because science is liable to change and new discoveries may lead to different classifications.
F. Nobody knows the way nature really is. Scientists classify nature according to their perceptions or theories. Science is never exact, and nature is so diverse. Thus, scientists could correctly use more than one classification scheme.

5. Even when scientific investigations are done correctly, the knowledge that scientists discover from those investigations may change in the future. **Your position, basically:** *Please read from A to D, and then chose one.*

Scientific knowledge changes:

A. because new scientists **disprove** the theories or discoveries of earlier scientists. Scientists do this by using new techniques or improved instruments, by finding new factors overlooked before, or by detecting errors in the original "correct" investigation.
B. because the earlier knowledge is **reinterpreted** in light of new discoveries. Scientific facts can change.
C. scientific knowledge APPEARS to change because the **interpretation** or application of the earlier facts can change. Correctly done experiments yield unchangeable facts.

D. scientific knowledge APPEARS to change because new knowledge is **added on to** earlier knowledge; the earlier knowledge doesn't change.

6. Scientists in different fields look at the same thing from different points of view. (for example H+ causes chemists to think of acidity and physicists of protons). This means that one scientific idea has different meanings depending on the field a scientist works in.
Your position, basically: *Please read from A to E, and then choose one.*

It is difficult for scientist in different fields to understand each other:

A. Because scientific idea can be interpreted differently in **one field** than in another.
B. Because scientific ideas can be interpreted differently, depending on the **individual** scientist's point of view or on what the scientist already knows.

A scientific idea will have the SAME meaning in all fields:

C. because the idea still refers to the **same real thing** in nature, no matter what point of view the scientists takes.
D. because all sciences are **closely related** to each other.
E. in order to allow people in different fields to communicate with each other. Scientists must **agree** to use the same meanings.

7. Scientists understand energy generally as any means by which matter can be changed. Seeing energy is difficult because it has many forms and properties.
Your position basically is: *Please read from A to D, and then choose one.*
Students should learn about energy:

A. to broadly locate and identify energy in natural systems.
B. to know that there are various sources and forms of energy.
C. to know the sources and forms of energy and how it flows from one place to another and to be able to note that energy can flow.
D. to know the sources and forms of energy and how it flows from one place to another, noting that energy can flow, and is not created or destroyed.

8. Science is an ever-changing discipline. Scientists are learning more and more about the world. This causes them to often focus on narrower and narrower aspects of science. This may impact student's science learning.

Your position basically is: *Please read from A to E, and then choose one.*

Science has major core topic areas student should:

A. **learn** the disciplines of science such as biology, chemistry and physics over a period of years to be able to learn about the new discoveries.

B. **be exposed** to the variety of new science learnings in the multiple areas of science, but focus on the areas of science such as Biology, Chemistry and Physics.

Science is integrated and has connections within the discipline

C. students should focus on an **aspect of** science while the teacher illustrates connections to other science areas not studied at the time such as biology, chemistry and physics.

D. students should focus on specific areas of science long enough to learn about the **topic** and its connections to related **properties of science**.

E. learn **about science** in an integrated fashion to gain insights into the breadth of science and other fields and not focus too long on particular areas of science.

III. Instructional Materials

9. Science textbooks may set the direction for the study of science topics, but may be limited in their depth and scope.

Your position, basically concerning science textbooks: *Please read from A to E, and choose one.*

A. are **focused** on content and assist students in understanding that content.

B. provide a **source and sequence** of information to guide students from one topic to another so that students are able to understand them.

C. provide a limited view of highlighted science ideas without links between ideas.

D. introduce many science ideas to students without connections among ideas.

E. provide science ideas and the connections among the ideas in science.

10. Science instructional materials (non textbooks) may set the direction for the study of science topics, but may be limited in their depth and scope.

Your position, basically is science materials: *Please read from A to E, then choose one.*

A. are **focused** on content and assist students in understanding that content.
B. provide a **source and sequence** of information to guide students from one topic to another so that they are able to understand them.
C. provide a limited view of highlighted science ideas without links between ideas
D. introduce many science ideas to students without connections among ideas.
E. provide science ideas and the connections among the ideas in science.

11. The challenge in science is to be able to provide students with both the breadth and depth of science. In the science high school courses you took as a student what were the primary instructional materials used? *Please read from A to F, and then choose one.*

A. textbooks
B. a mix of different curricular programs
C. readings
D. problems and investigations
E. educational technology
F. field work

12. Instructional materials, textbook and other resources are used in science teaching. In the **current** science classes you now teach, what are the primary instructional materials used? *Please read from A to F, then choose one.*

A. textbooks
B. a mix of different curricular programs
C. readings
D. problems and investigations
E. educational technology
F. field work

IV (This section is optional. You may choose to be anonymous.)

If you are willing to be contacted to discuss further participation in this study about beliefs and practices, please include your name and telephone number.

Name ______________________________

Telephone number _____________________________

Thank You

Please return to:

Francis Eberle
(Home Address)

Appendix C: Teacher Study Participation Confirmation

July 2, 2000

Dear,

Thank you for agreeing to participate in my study about how middle school science teachers think about and teach science. I have interviewed three of the seven participating teachers so far and they are all looking forward to seeing the results of this study.

This letter is confirming your willingness to participate, and to allow you to suggest a date and time when I can interview you. The interview will last about 1 hour. If you come to school prior to the beginning of the school year, some time during those days might be the best time for this interview. Would you complete the information below and either mail, call or email mail the information to me. My email address is francis.eberle@state.me.us.

If you have any questions between now and next fall, please feel free to contact me at my office (287-5881 or 287-6491) or at my home (725-2097).

Best wishes for a relaxing summer.

Sincerely,

Francis Eberle

Name: ____
School: ____

Best date and time for an interview: __________________________

Next best data and time: ____________________________________

I may be contacted to confirm these dates at the following telephone number or email in August or early September.
Telephone #: ________________

Email address: ________________________

Appendix D: Administrator letter

August 18, 2000

Dear,

I am writing at the request of Helen regarding a study I am doing of Maine middle school science teachers. This study will exam how middle school science teachers think about science as a discipline and then what science they teach in their classes. As a former middle school teacher, I know that there are many factors influencing decisions for teaching a particular lesson or unit, and it is well documented that there are a variety of effective ways to teach depending on the day, the topic or particular students. However, educational researchers have failed to ask teachers about their fundamental beliefs on science for lessons which were observed.

I am currently a Ph.D. student in the Educational Studies program at Lesley College in Cambridge, Massachusetts. Helen, one of your science teachers, has agreed to participate in the study after being identified by her response on an earlier survey.

I will be working with a total of 6 middle school science teachers. To accomplish my goals, several types of data will be collected for each teacher. The following is a list of the data:

A. 1 to 1-1/2 hour interview (in the spring or summer of 2000)
B. 8-10 observed classes (Fall 2000)
C. Classroom materials used in observed classes (Fall 2000, e.g. handouts, lesson plans.).
D. 1 to 1-1/2 hour post-instructional interview (Fall 2000)

I am asking your permission for Helen to participate in this study. She does not need to prepare anything for the interview or observations. The only "extra" time she would have to commit to this study is for the two interviews. Helen's and the school's anonymity will also be protected throughout the study and in the final dissertation.

If you have any questions, you may call me at my office (287-6491) or at my home (725-2097). You may also contact my dissertation advisor, George Blakeslee (617 343-8488), for information or references. I will contact you soon about this study.

Sincerely,
Francis Eberle

Appendix E: 1st Interview Questions

A. Demographic

I am interested in learning about your teaching load and responsibilities for next year.

1. What is your teaching load next year?
    a. How many preparations will you have?
    b. How is that load confounded/helped by your teaching science?
    c. How are students in your science classes grouped: by subject, student ability?
    d. What other duties will you have?
    e. What other committees will you be a member of and how do they affect your teaching of science?
    f. Are there committees or duties you would like to have? Why?
    g. Have you ever worked on a curriculum project before? If so when?

2. How do parents interact with you and the school?
    a. What role do they have in influencing what science you teach?
    b. How do you involve parents or the community in your science classes?

B. Preparation: (High School & College)

I am interested in your background preparation for being a science teacher.

1. What was the science teaching in your high school science classes like? (textbooks, projects, laboratories). Can you provide percentages of the various methods used?
2. Was there grouping of students by ability in these classes/schools?
3. How did the science in these classes match your ideas of science?
4. What was the best part of the science classes?
5. What would you have changed if you could?
6. What was the teaching in your college science classes like? (textbooks, projects, laboratories). Can you provide percentages of the various methods used?
7. Was there grouping of students by ability in these classes/schools?

8. How did the science in the classes match your ideas of science?
9. What was the best part of the science classes?
10. What would you have changed if you could?
11. When did you decide to become a science teacher?
12. What was it that helped you to make the decision to teach science?
13. What undergraduate (and graduate) schools did you attend?
14. What were your area(s) of content specialization?
15. How well prepared do you feel you are to teach science?
16. What learning in science has provided you with the most confidence to teach science?
17. Where do you go now for new learning in science?
18. Have the recent state or national standards affected your knowledge about science?
19. Have the recent state or national standards affected your teaching of science?

C. Instruction & Science

In this study I am interested in what you think about science?

1. If you had a philosophy of science, what would it be?
    a. What are your specific goals for teaching science?
    b. Do you have a curriculum, which you follow?
    c. What textbooks and/or supplementary instructional materials do you use to teach your students science?
    d. Did you select the textbook? Supplementary instructional materials? (If not, how were they chosen?)
    e. What other resources do you use to teach science?
    f. Who makes decisions about what science is taught in your classes?
    g. If you could add something in your curriculum for your science classes, what would you add?
    h. If you remove something from your curriculum for your science classes, what would you take out?

i. If you could teach your science class any way you wanted, what would you do differently.

2. Do you believe that there is a culture or nature of science? (If so please describe.)
    a. Is it possible for middle school students to understand this culture?
    b. How do you help your students understand this culture?
    c. What sorts of things do not help students to understand this culture of science?
3. What is your philosophy of teaching science to your middle school students?
    a. How do you feel your students learn science best?
    a. Describe your teaching that helps them to learn science.
    b. Describe teaching that makes learning science difficult for students.
    c. How do you determine what your students know?
    d. How often do you assess your students' knowledge about science?
    e. What sort of grouping do you create in your science classes?
        I. Ability grouping – How do you teach the different groups of students? Why are there different levels of students?
        II. No ability grouping – How do you teach the different groups of students all in one class? Why are all students together?
    f. How do the topics in your science classes fit into the overall science topic sequence for students in your school?
    g. Describe your students.

D. Preparation for the fall interviews

1. Do you have any questions about the next step?
2. Do you have any questions about what I am going to do with this information?

Subject Matter Structure Task Questionnaire

To try to understand your thinking about science as a discipline, please complete the following questionnaire. This questionnaire is intentionally vague and there are no right or wrong answers.

1. What topics make up the science you teach?

2. If you were to make a diagram of these topics, what would it look like?

3. Have you ever thought about science this way before? Please explain.

Appendix F: Classroom Observation Form

Teacher: Observer:
Unit: Date:
Instructional Type: Other:

Science Topics	Teacher Presented/Response	Student Question/ Response	Curriculum Presented	Other sources (note source)
1. Nature of Science				
Scientific World View				
Scientific Inquiry				
The Scientific Enterprise				
2. Nature of Mathematics				
Patterns and Relationships				
Mathematics, Science & Technology				
Mathematical Inquiry				
3. Nature of Technology				
Technology & Science				
Design & Systems				
Issues in Technology				
4. Physical Setting				
The Universe				
The Earth				
Processes that Shape the Earth				
Structure of Matter				
Energy Transformations				
Motion				
Forces of Nature				
5. Living Environment				
Diversity of Life				
Heredity				
Cells				
Interdependence of Life				
Flow of Matter and Energy				
Evolution of Life				
6. Human Organism				
Human Identity				
Human Development				
Basic Functions				
Learning				
Physical Health				
Mental Health				
7. Human Society				
Cultural Effects & Behavior				
Group Behaviors				
Social Change				
Social Trade-offs				
Political & Economic Systems				
Social Conflict				
Global Interdependence				

Classroom Observation Form (page 2of 2)

Teacher: Date:

Science Topics	Teacher Presented/Response	Student Question/ Response	Curriculum Presented	Other sources (note source)
8. Designed World				
Agriculture				
Materials / Manufacturing				
Energy Sources & Use				
Communication				
Information Processing				
Health Technology				
9. Mathematical World				
Numbers				
Symbolic Relationships				
Shapes				
Uncertainty				
Reasoning				
10. Historical Perspectives				
Displacing Earth from Center of the Universe				
Uniting Heavens & Earth				
Relating Matter & Energy and Time & Space				
Extending Time				
Moving Continents				
Understanding Fire				
Splitting the Atom				
Explaining Diversity of Life				
Discovering Germs				
Harnessing Power				
11. Common Themes				
Systems				
Models				
Constancy & Change				
Scale				
12. Habits of Mind				
Values & Attitudes				
Computation & Estimation				
Manipulation & Observation				
Communication Skills				
Critical Response Skills				

Appendix G: 2nd Interview Questions - Fall/Winter 2000

A. Ground the teacher back into the lessons taught in the observations.

1. Which units/lessons did you enjoy teaching the most? Why?
2. Which units/lessons do you think were the most successful?
3. Which of the units did you think the students enjoyed the most? Felt the most success with? Why?
4. What influence did my being in your classroom have on: Your students? Your teaching? You? (in terms of personal influence, changes in planning, time commitments, behavior, etc)
5. What should students know/be able to do now that they have been in your science class for a semester? What would be the minimum you would be happy with? What would be the best possible outcome?

B. The teachers' rationale (intentions vs. reality) for the teaching of science.

6. Why were the observed lessons/units taught in this order and manner?
7. What advantages/disadvantages do you find with this sequencing?
8. How do you determine the length of time you spend on a topic?
9. Is there science you would like to teach as a part of this unit? What were the limitations that prevented you from including those science ideas?
10. Do you plan on making any changes in this unit for next year? If so what would the changes be and why would you make them?
11. If given total freedom, would you change your teaching of science? How and why?

C. Questions specific to teaching science.

12. Why do you teach the way you do?
13. What criteria do you use in selecting these materials?
14. On what basis do you prioritize materials/activities when you have more material than you have days in a unit?
15. What role do text-provided materials play in your teaching? Your thinking about teaching science?

D. Teachers' perception of their own subject matter knowledge.

16. You described earlier that you have an undergraduate specialization as ____. Does this area of specialization affect the manner in which you teach science and other topics in science?
17. How do you react to the options for answers for the following statement from the survey I asked earlier: Statement: Some educators have suggested students will better understand science if they first grasp certain fundamental concepts applicable across science areas:
    a. *It is best to have students learn separate components of science (such as cellular structures in biology) and have an opportunity to apply the separate ideas in new situations as an assessment.*
    b. *It is best for students to learn science through connecting science concepts in different contexts such as the flow of energy in ecosystems and photosynthesis as they build knowledge about the discipline of science.*
18. How do you react to the options for answers for the following statement from the survey I asked earlier: *Science is an ever-changing discipline. Scientists are learning more and more about the world. This causes them to often focus on narrower and narrower aspects of science. This may impact students' science learning.*
    a. *Students should be exposed to the variety of new science learnings in the multiple areas of science, but focus in the areas such as Biology, Chemistry and Physics.*
    b. *What about: Students should focus on an aspect of science at one time while the teacher illustrates connections to other science areas not being studied at the time such as biology, chemistry and physics.*

E. Complete the SMS diagram/concept map.

23.Diagram.

F. The teachers elaborate on their diagrams.

24. Describe in words, what you have written on paper.
25. How did you select the topics and did you exclude any?
24. What do the connections among your topics mean? (if appropriate)
25. What specifically do you mean by (use a term from the paper)
26. If I substituted one term with another (for instance; animals for zoology), would these two terms convey the same idea? Why or why not?
27. Are these topics you listed of equal scale or magnitude? Please explain.
28. What are the most important content topic/themes that you think should be emphasized in science?
29. Are those important topics/themes listed as a part of your diagram? Why or why not?
30. Would these topics/themes fit and/or be appropriate in your diagram?
31. Is there a sequence to the topics you have in your diagram? Why and why not?
32. National and State standards, and some scientists recommend that science should be taught by integrating aspects within the discipline and making connections to the world. Is this is a reasonable task for middle school science?
33. How successful do you think you were/are in doing so in the unit I observed? (If needed): What are the things that limit you from integrating the ideas and making connections?
34. What might you change if you could about the life, physical and earth science categories of science?
35. Have you ever thought about science with those types of categories or changes? Why or why not?

G. Questions for the three teachers who completed the diagram two times.

36. Have your views changed about science from when you first completed this diagram at the beginning of the study? If so how and why?
37. Did the act of completing this form at the beginning of this study have any influence on how you have filled it out now? On your teaching?

H. Look at both diagrams and ask to compare and contrast their two diagrams.

38. How did it make you feel to make these diagrams?
39. Do you think the structure of content you provided in the diagram is evident in your classroom teaching? Why or why not?

Appendix H: Teacher Backgrounds

Daniel - South Middle School

The South Middle School is a traditional middle school with grade level teams and 90-minute blocks of classes. The school was originally designed as an open school without walls. Many temporary walls have been put in place to divide the large open space into separate classrooms. The noise level is high because students' voices can be easily heard. Daniel is the 6th grade science teacher. Prior to this particular year of the study, he taught integrated mathematics and science in a double block for five years. With the district's adoption of a specific mathematics curriculum and after a review of curriculum based on the state standards, mathematics and science were separated so that Daniel teaches only science. This past summer he worked on the new science curriculum for the middle school. Daniel has taught science for more than 10 years.

He had a class load of five classes of twenty-three students. In addition to his regular teaching load, he runs an ecology club during the day's activity block. When he started the club four years ago, he had twelve students; this past year he had one hundred and forty two students. The students have done water quality studies for the city, and bird banding of the eastern bluebird through a study with Cornell University via the Internet. He is enthusiastic about working with students in both his classroom and in the more informal club context.

Daniel also wants to help students of all abilities stretch their thinking and reflect on their work and development over the sixth grade year. He does this with four open-ended independent projects - one each quarter - selected by the students. He also uses other open-ended problem solving activities during the year. His intent in using these projects and activities is to help his students learn about areas of their interest and to grow into better students by having the flexibility to go as far with a topic as they want, and to be able to reflect on their experiences within the project.

> *You give them activities to do open-ended kind of situations, see how far you can go with this. I like open-ended activities, especially when you have special ed kids and slow learners and then average kids and then your really high-flyers, gifted and talented all sitting in one classroom.*

He has an open door policy for parents to participate in class and some do volunteer but not many. He shares an additional school responsibility with his team members - the morning duty supervising students when they arrive at school before classes begin.

Daniel describes his students when they first come to him as timid, shy and somewhat reluctant. He notes that they work hard for him in the fall because they need to prove to themselves and to their parents that they can do sixth grade work. After mid-year, they loosen up a bit, letting social aspects come into play. He tempers this pattern by focusing on general student interactions.

> *Well, I try to breed a mindset in class right in the beginning of class of respect. Respect of other peoples' ideas, things and property, things like that. If someone thinks something different from you, it doesn't make them wrong it makes them different.*

Patricia: Coastal Middle School

Patricia teaches seventh grade at the Coastal Middle School in a southern Maine town, located in a growing middle class suburban community. Patricia teaches five science classes with a total of 106 seventh grade students. All the classes are heterogeneously grouped; the class preparations are the same.

Patricia is the department head for the science department, and a member of a seventh grade cross-disciplinary team. The middle school team of teachers meets as a team every day; the department heads in the schools and team leaders meet once a week with the principal. She has freedom to decide much of what is in her curriculum. She has been teaching for seven years.

She has participated on a state committee about the state assessment test. She was involved with designing and writing science questions for one year of the state's eighth grade science assessment, the Maine Educational Assessment.

Patricia greatly enjoys her job as a science teacher.

> *I have a passion for science. I love what I do. And they allowed me to teach whatever I wanted to teach, the blanket, the whole spectrum for what I was supposed to teach.*

Her classroom has many posters on the walls, and large science artifacts around the room, such as a cross section of a large tree, bones and live animals. Student work is displayed whether from a previous unit or a work in progress from a current unit. There are tables for students to sit at and work.

She describes her instructional techniques as being traditional, but she thinks about how she is teaching and whether she can improve.

> *We do a lot of demonstration and we do a lot of labs. I do a lot of stuff that I don't call a lab. Like my stock room is full of bones. I put out all the bones and we do joints, we put bones together. Those kinds of things. I still do teach vocabulary, because so much the kids have never had before. They learn parts of the heart. I am not a project person. I do some writing projects that kind of thing. As far as testing, and quizzing and that kind of thing, I am probably pretty traditional.*

She feels strongly that her job is to help students understand science and she uses concrete approaches to help her students learn.

> *The funny thing about middle school kids developmentally is they can sometimes do real higher level and the next day they can't and then a couple a weeks later they are way back to that higher level. What I do is a lot of manipulatives. You bring it down to be very concrete. If I want them to understand how this works then I am going to make it very concrete.*

The community strongly supports education. There is a highly active parent group. Patricia has a telephone and computer in her room and parents leave voice mails and email all the time. She provides parents with a lot of information about their children and parents frequently come to team meetings. She feels she is expected to communicate with parents.

> *I have a phone in my room and parents leave me voice mail all the time and email me and I get back them. Parents come into to team all the time. I feel we have high parent involvement. I am expected to call parents when kids make huge swings you know those kinds of things. And parents ask me to look for certain things and I do follow up*

When asked to describe her students she said, *I love them, they are so cute!* Her enthusiasm for her students and teaching science is contagious

Robert: Central Valley Middle School

Robert teaches eighth grade in Central Valley Middle School in the western region of Maine. Central Valley Middle School is located in a town with a large paper mill. The surrounding area, however, is quite rural. Robert has taught for more than 17 years and most of those years have been in Central Valley. The nearby mill has been doing well and the town has benefited from a new school and plenty of instructional materials and equipment for the students.

The composition of teachers includes teams called pods for each group of students. Robert teaches four mostly heterogeneous classes. Two of the classes have ½ of the algebra students in each while the other two science classes have no algebra students. Other than the mathematics grouping, there is no tracking in the science in the eighth grade. Robert has taught for ten years at Central Valley. He has also been the science curriculum chair. When he first started at Central Valley he taught earth science and now teaches some physical and life science. Robert is very energetic and positive about his job, and seems to enjoy working with his students.

Robert has duties other than teaching during the year, including lunch duty, an academic enrichment and an academic assistance class. The two non-subject classes were established to either help those students who lag behind and need help in a particular class, or to provide an opportunity for other students to learn about things other than what is regularly taught in school. Robert is now teaching about structures in the enrichment class. Students do many hands on activities; their structure models were on display in his classroom. He is currently a member of the health and science curriculum advisory committee. The science curriculum committee is involved in aligning and rewriting the science curriculum so that it meets the state's standards called *Learning Results*.

Celeste: Oceanside Middle School

Celeste teaches sixth grade at Oceanside Middle School. Celeste has been in the education profession for some time, but has had only seven years in pubic education. Previously she was a teacher in informal education organizations. The Oceanside Middle School is a traditional middle school with teams of teachers working with one group of

students. Celeste has four science classes and one writing class. Each has 24-26 students. The town of Oceanside is an affluent community compared to most Maine communities. There is no state sponsored free and reduced lunch program at Oceanside as the population does not have enough students below the poverty line to meet the state threshold of 5% to qualify it. For duties outside of her regular teaching she has recess, lunch, bus and study hall duties. These duties are shared throughout the schools year with her team members. She also shares the position of team leader with her team members.

Competition and grades are important to parents in this community. When Celeste was asked about the students in Oceanside, she first mentioned the competitive nature of the town. Students often get paid for A's. She thinks that parents feel better if their child gets an A, when their neighbor's child gets a C. In this competitive context, there is strong parental support for education and there are several initiatives to accelerate students.

One such program is called Specific Academic Aptitude (SPAA) for students who have a specific aptitude in a particular academic area. This program is one of the gifted and talented programs for about 5 % of students who are pulled out of their classes for this seminar class. The SPAA program adds an additional load for Celeste, as she has to vary her class materials depending on the number of students in the SPAA program and out of her class at any one time.

Celeste also talks about the students as being nice kids, and she enjoys spending time with them. They have a sense of humor and want to work hard. Discipline is not a big problem in this school because they want to succeed. They are generally eager learners.

Tom: Kennebec Middle School

Tom is an eighth grade science teacher in the Kennebec Middle School, in a once thriving town for the papermaking industry. Today the town has few jobs so the people go to other places for work. Tom grew up in the town next door to the Kennebec Middle School; when he was a kid, the town was thriving. With the closing of the paper mills and

the change in what type of workers are needed in the mills, the demographics and the population are dramatically different.

The Kennebec Middle School is a traditional one with teams of teachers at each grade level, all working with a similar group of students. Tom has a teaching load of five classes; four of them are science and one is literature. He has 102 students, 82 in science classes and 20 in literature class. He likes his current schedule because he has the first hour of every day open for his own class preparation. All students are heterogeneously grouped in science at the Kennebec Middle School, except for one class, which has no students taking algebra. Even though he has taught at the Kennebec Middle School for just three years, he has taught for more than a total of 17 years.

He has no other duties in the school, but he always eats lunch with the students. He feels this keeps him connected to them. The science teachers in his district are in the process of aligning the science curriculum with Maine's *Learning Results* and Tom is on that committee. Tom is not on any other committees. He has worked in two other districts where he has done similar curriculum alignment work with standards.

The parents support teachers and the community supports education. There isn't much parent involvement in his classes, but many parents have participated in the team building activities at the youth adventure activities in the beginning of the school year. He doesn't get many parents coming into schools, but he also doesn't get any complaints from them. Tom says there aren't many top end students in the school, and there are a lot of special education students. He says overall they are good kids and they know discipline. He describes his current students as great kids.

Tom also owns a white water rafting outfitter company on a Maine River. When he is away from school, he is busy with this company. He has started to bring his students from the Kennebec Middle School on white water rafting trips as a way for developing more cohesion among the students. He knows many outdoor adventure instructional techniques from his work in his business and he now incorporates them in his classes as a way to develop cooperation among his students.

Helen: Willow Middle School

The Willow Middle School is a grade 6-8 middle school in a fast growing suburban community. The town's growth is related to its being within commuting distance to a city and being on several lakes where many new people are moving and where new schools are continuously being built. Helen now teaches sixth grade; it is her first year at this grade level. It is fourth year of teaching. Her assignment is a self-contained classroom with three subject preparations: science, math and language arts. She teaches all the science for her sixth grade team; one of her teammates teaches all of the social studies for her team.

Previously Helen taught seventh grade science and math. With language arts added into her sixth grade assignment, she is concerned that it will make teaching science more difficult. Her classes have about 24 heterogeneously grouped students in each one. She was excited about this sixth grade class because she has piloted some of the curriculum previously in the seventh grade.

> *Some of the things I did last year are in the book for this year. And it looks like I will be able to use the things on cells that I just piloted last year. Some of the piloting this past quarter, I believe I will be able to use again next year. I am really excited about using again next year.*

For being new to teaching, Helen participates in several of the school's various professional responsibilities. She is on the school's science and wellness committees, in charge of developing the quarterly wellness newsletter and of sending birthday cards to staff. Her other school duties include monitoring the morning hall and break times with her team in the middle of the morning.

Helen encourages parents to come into her classroom to volunteer and to assist her. Mostly they just come for the quarterly parent conferences. And Helen has done community service type activities with her team. Last year, with her grade level team, she took students to a therapeutic riding center for disabled children. The students dug holes for fence posts, strung fences and cleared trails and pastures.

Helen is enthusiastic and enjoys working with students. She has a high energy level and is positive about her work. She says her students are anything but boring. She

enjoys them immensely, and thinks hard about how to meet their various and changing needs.